Final Feasibility Study

Bradford Island Upland Operable Unit

Cascade Locks, Oregon

U.S. Army Corps of Engineers

Portland District

P.O. Box 2946

Portland, OR 97208-2946

August 11, 2017

US Army Corps
of Engineers®

This page intentionally left blank

Executive Summary

The United States Army Corps of Engineers (USACE), as the lead federal agency for the CERCLA response at the Bradford Island Upland Operable Unit (OU), prepared this Feasibility Study (FS) in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended [42 U.S.C. 9601 et seq.], and the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) [40 CFR 300]. The FS process was in accordance with Executive Order 12580 and Engineering Regulation (ER) 200-2-3. As such, the methodologies presented in the FS follow the federal CERCLA process for development and subsequent selection of a preferred remedial alternative. The final Remedial Investigation (RI) was completed in June 2012.

The FS evaluates a range of remedial alternatives to clean up the Bradford Island Upland OU, encompassing the eastern end of the island and includes four areas of potential concern (AOPCs): the Landfill AOPC, Sandblast Area AOPC, Pistol Range AOPC, and Bulb Slope AOPC. The remedial alternatives are evaluated according to CERCLA requirements and US EPA policy and guidance. CERCLA establishes standards and procedures for evaluating remedial alternatives, selecting a remedy, and performing cleanup. Following publication of the final FS, USACE will issue the Proposed Plan identifying the preferred remedial alternative for the Bradford Island Upland OU. Formal public comment will be requested on the Proposed Plan. After public comments on the Proposed Plan are received and evaluated, USACE will select the final remedial alternative and issue the Record of Decision.

The FS builds on a series of studies completed over 14 years that are documented in the Final RI (URS, 2012). The RI describes:

- A conceptual site model for the Bradford Island Upland OU;
- Physical and biological interactions, including fate and transport of contaminants at the site;
- The nature and extent of contamination; and
- The risk that contamination presents to people and animals that use Bradford Island.

Scope of this FS

The scope of this FS only includes evaluation of the Upland OU. The River OU is addressed in a separate FS. The baseline risk assessments were also developed separately and accompany each FS for the respective OU. These baseline risk assessments were conducted after completion of the RI. At the time of the RI, only a screening level risk assessment was conducted. Conclusions from the screening level risk assessment recommended a baseline risk assessment be conducted. This baseline risk assessment was subsequently completed in conjunction with the FS and is included as an appendix to this report.

In formulation of the alternatives for the Upland OU, this FS also takes into consideration the potential for erosion to occur at the Landfill AOPC. Geotechnical analyses conducted during and after the RI indicated that the Landfill AOPC has potential for erosion and mass wasting into the River OU. Therefore, alternatives in this FS were formulated to address potential erosion in the Landfill AOPC as well as the need for remedial action. Erosion in the Bulb Slope AOPC is assumed to also be occurring; however, contaminant concentrations do not exceed risk based thresholds, so remedial action for the Bulb Slope is not necessary to protect upland human and ecological receptors. However, there is possibly a need to mitigate erosion of contaminants in the Bulb Slope AOPC into the river, and this will be addressed in the River OU FS with a geotechnical analysis.

Risk Assessment

The baseline risk assessments conducted as part of the FS estimated risks to people (human health) and plants, invertebrates, and wildlife (ecological receptors), resulting from exposure to contaminants in the absence of any cleanup measures. Risk assessment findings were used to develop remedial alternatives for the Bradford Island Upland OU. The findings of these risk assessments are summarized as follows:

- Carcinogenic polycyclic aromatic hydrocarbons (cPAHs) contribute the most risk to human health. As such, cPAHs are identified as a risk driver contaminant for human health based on the magnitude of risk and relative contribution to total human health risks.
- Risks to people are primarily associated with exposure to soil under the fishing platform scenario for Native American tribal members. These risks exceed the US EPA's acceptable lifetime excess cancer risk range threshold of $1x10^{-4}$.
- There are also risks to people associated with both the outdoor maintenance worker and construction worker exposure scenarios, but these risks are minor relative to that of the fishing platform scenario. Risks for the outdoor maintenance worker and construction worker are generally *de minimis* (lifetime excess cancer risks are less than $1x10^{-6}$) or fall within the US EPA's acceptable lifetime excess cancer risk range of $1x10^{-4}$ to $1x10^{-6}$.
- Ecological risks are greatest for exposure to metals, specifically: chromium, copper, lead, mercury, and nickel. The majority of risks are most significant for the vagrant shrew (representing the terrestrial mammal receptor); however, there are some notable risks to the American robin (representing the invertivorous bird receptor) as well as plants and invertebrates.

Remedial Action Objectives and Preliminary Remediation Goals

Two remedial action objectives (RAOs) have been identified based on the risk assessments. The RAOs describe what the cleanup action should accomplish at the Upland OU in order to address the identified risks. The RAOs are:

- **RAO1**: Reduce to acceptable levels the exposure risk of the fishing platform user to soils contaminated with cPAHs.
- **RAO2**: Reduce to acceptable levels the exposure risk of ecological receptors to soils contaminated with chromium, copper, lead, mercury, nickel, and total high molecular weight polycyclic aromatic hydrocarbons (HPAHs).

Preliminary Remediation Goals (PRGs) were developed for each RAO; they represent concentrations that are believed to provide adequate protection of human health and the environment. These PRGs for a given contaminant are applied as an average across each

AOPC to guide development of remedial alternatives. PRGs are not final cleanup levels. USACE will select cleanup levels in the Record of Decision.

Development of Remedial Alternatives

PRGs were developed for each risk-driver contaminant within each AOPC warranting remediation. Of the four AOPCs within the Bradford Island Upland OU, only two warrant remedial action: the Landfill AOPC and the Pistol Range AOPC. As such, remedial alternatives were formulated for each of the two AOPCs (no remedial action was warranted for the Sandblast AOPC or Bulb Slope AOPC). A synopsis of alternatives for each of the two AOPCs is summarized below.

Landfill AOPC Alternatives

- **Alternative L1 – No Action**: Alternative L1 is the no action alternative. It provides a basis for comparison of the other remedial alternatives and is required by CERCLA. The present value of the cost for Alternative L1 is assumed to be $0.
- **Alternative L2 - Landfill Cutback and Land Use Controls**: Alternative L2 addresses the area of the landfill that is recommended to be cut back due to the potential for erosion and mass wasting. An estimated 1,988 cubic yards (CY) of material would be removed under Alternative L2. The estimated present value of the cost of Alternative L2 is $661,199.
- **Alternative L3 - Landfill Cutback, Additional Shallow Excavation and Backfill, Land Use Controls**: Alternative L3 includes the landfill cutback and additional shallow excavation and backfill to further reduce exposure point concentrations. The volume of contaminated soil removed would be approximately 3,092 CY. The estimated present value of the cost of Alternative L3 is $976,080.
- **Alternative L4 - Landfill Cutback, Capping and Land Use Controls**: Alternative L4 includes the landfill cutback in Alternative L2, additional excavation in the sloped area required by the landfill cutback, and capping in other areas to further reduce exposure point concentrations. The estimated present value of the cost of Alternative L4 is $882,654.
- **Alternative L5 - Landfill Cutback, Complete Landfill Excavation and Backfill**: Alternative L5 includes the landfill cutback in Alternative L2 and additional excavation and backfill to remove all of the landfill material. The deep excavation is proposed due to concerns that future human actions could alter the exposure point concentrations of COCs or CECs to levels that are not protective. The estimated present value of the cost of Alternative L5 is $2,432,840.

Pistol Range AOPC Alternatives

- **Alternative PR1- No Action**: Alternative PR1 is the no action alternative. The present value of the cost for Alternative PR1 is assumed to be $0.
- **Alternative PR2 – Shallow Excavation and Backfill**: Alternative PR2 addresses the assumed remedial footprint by clearing and grubbing, excavating the top 3

feet of soil, backfilling with imported clean material, and reseeding and establishing the backfilled area with native vegetation. The estimated present value of the cost of Alternative PR2 is $76,131.

- **Alternative PR3 – Capping and Land Use Controls**: Alternative PR3 addresses the assumed remedial footprint by clearing and grubbing, covering the to-be capped area with a geotextile warning layer, capping with 3 feet of imported clean material, and reseeding and establishing the capped area with native vegetation. The estimated present value of the cost of Alternative PR3 is $123,307.

Detailed Evaluation and Comparative Analysis of Remedial Alternatives

The remedial alternatives were evaluated in accordance with CERCLA guidance. CERCLA has nine criteria (two threshold criteria, five balancing criteria, and two modifying criteria) applicable for evaluating alternatives. The two CERCLA threshold criteria, which must be met before the others can be considered, are overall protection of human health and the environment and compliance with applicable or relevant and appropriate requirements (ARARs) of federal and state environmental laws and regulations. The five balancing criteria are:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

The two modifying criteria are state/tribal acceptance and community acceptance. USACE will evaluate state, tribal, and community acceptance of the selected remedial action in the Record of Decision following the public comment period on the Proposed Plan.

Table of Contents

1 Introduction 1-1
- 1.1 Purpose of the Feasibility Study 1-1
- 1.2 The Feasibility Study Process 1-1
- 1.3 Definitions for the Feasibility Study 1-3
- 1.4 Document Organization 1-6
- 1.5 References 1-7

2 Site Setting, RI Summary, and Current Conditions 2-1
- 2.1 Environmental Setting 2-1
- 2.2 Investigation History 2-14
- 2.3 Data Used in the FS 2-26
- 2.4 Conceptual Site Model (CSM) 2-29
- 2.5 References 2-40

3 Risk Assessment Summary 3-1
- 3.1 Baseline Ecological Risk Assessment 3-2
- 3.2 Baseline Human Health Risk Assessment 3-5
- 3.3 Risk-based Threshold Concentrations 3-11
- 3.4 Key Findings of the Baseline Risk Assessments 3-14
- 3.5 Cumulative Risk Considerations 3-15
- 3.6 To Be Considered (TBC) Considerations 3-16
- 3.7 Land Use Considerations 3-16
- 3.8 References 3-18

4 Remedial Action Objectives and Preliminary Remediation Goals 4-1
- 4.1 Development of Remedial Action Objectives 4-1
- 4.2 Applicable or Relevant and Appropriate Requirements (ARARs) 4-2
- 4.3 Process for Development of Preliminary Remediation Goals 4-3
- 4.4 Preliminary Remediation Goals 4-5
- 4.5 References 4-6

5 Identification and Screening of Remedial Technologies 5-1
- 5.1 Review and Selection of Representative Process Options 5-2
- 5.2 Land Use Controls 5-10
- 5.3 Monitoring 5-13
- 5.4 Ancillary Technologies 5-14
- 5.5 Summary of Representative Process Options for the FS 5-14
- 5.6 References 5-15

6 Development of Remedial Alternatives 6-17
- 6.1 Framework and Assumptions for Making Technology Assignments 6-17
- 6.2 Common Elements for all Remedial Alternatives 6-21
- 6.3 Detailed Description of Remedial Alternatives 6-24

6.4 References 6-29

7 Analysis of Alternatives 7-1
7.1 Overview of Evaluation Criteria 7-1
7.2 Detailed Analysis of Alternatives: Landfill AOPC 7-5
7.3 Detailed Analysis of Alternatives: Pistol Range AOPC 7-11
7.4 Managing COCs and CECs Other Than Risk Drivers 7-14
7.5 Comparative Analysis 7-15
7.6 Summary of Findings and Path Forward 7-18

Appendices

Appendix 1. Final Report: Baseline Human Health and Ecological Risk Assessment, Upland Operable Unit, Bradford Island, Cascade Locks, Oregon, April 2016
Addendum: Supplemental Risk Analysis for the Tribal Fishing Receptor, June 2017
Appendix 2. Memorandum for Record, Slope Stability Analysis, 30 October 2015
Appendix 3. Bradford Island Upland Operable Unit Feasibility Study, Detailed Cost Estimates
Appendix 4. Response to Comments, Oregon DEQ and Yakama Nation Draft Feasibility Study Review

[Figures and Tables are provided separately]

Figures

Figure 2-1. Bonneville Dam Complex
Figure 2-2. Bonneville Dam in Relationship to Other Dams
Figure 2-3. Upland Operable Unit Overview
Figure 2-4. Photo of Tribal Fishing Platforms
Figure 2-5. Sandblast Area AOPC Operational Areas
Figure 2-6. Landfill AOPC Operational Areas
Figure 2-7. Pistol Range AOPC Sampling Locations
Figure 2-8. Bulb Slope AOPC Metals and PCBs in Surface Soil
Figure 3-1. Landfill AOPC CEC Locations above RBCs
Figure 3-2. Sandblast Area AOPC CEC Locations above RBCs
Figure 3-3. Pistol Range AOPC CEC Locations above RBCs
Figure 3-4. Bulb Slope AOPC CEC Locations above RBCs
Figure 3-5. Landfill AOPC COC Locations above Occupational RBCs

Figure 3-6. Landfill AOPC COC Locations above Hypothetical Fishing Platform RBCs
Figure 3-7. Sandblast Area AOPC COC Locations above Occupational RBCs
Figure 3-8. Sandblast Area AOPC COC Locations above Hypothetical Fishing Platform RBCs
Figure 3-9. COI, COPC, COC, and Risk Driver Screening Process
Figure 6-1. Landfill Setback
Figure 6-2. Landfill Cutback and Sample IDs
Figure 6-3. Alternatives L3 and L4 Remedial Footprints
Figure 6-4. Alternative L5 Excavation Footprint
Figure 6-5. Alternatives PR2 and PR3 Remedial Footprints

Tables

Table 2-1. Occurrence and Status of Threatened, Endangered, and Sensitive Species in the Bradford Island Vicinity, Oregon
Table 2-2. State and Federally Listed Anadromous Salmonid Species
Table 2-3. Designated Beneficial Uses – Mainstem Columbia River
Table 2-4. Beneficial Use Designations – Fish Uses, Mainstem Columbia River
Table 2-5. Data Summary for Landfill AOPC Samples, Bradford Island – Upland Operable Unit
Table 2-6. Data Summary for Sandblast Area AOPC Samples, Bradford Island – Upland Operable Unit
Table 2-7. Data Summary for Pistol Range AOPC Samples, Bradford Island – Upland Operable Unit
Table 2-8. Data Summary for Bulb Slope AOPC Samples, Bradford Island – Upland Operable Unit
Table 2-9. Data Summary for All Four AOPs Combined, Bradford Island – Upland Operable Unit
Table 2-10. Data Summary for Reference Area Samples, Bradford Island – Upland Operable Unit
Table 2-11. Upland OU Limited and Estimated Data Sets Bradford Island Remedial Investigation
Table 3-1. Summary of Upland OU Hazard Quotients for CECs
Table 3-2. Summary of CECs and Selection of Risk Drivers for Ecological Receptors
Table 3-3. Summary of Upland OU Cancer Risk and Noncancer Health Hazard
Table 3-4. Summary of COCs and Selection of Risk Drivers for Human Health Exposure Scenarios
Table 3-5. Exposure Assumptions and Dose Equations for the American Robin (Turdus migratorius)
Table 3-6. Exposure Assumptions and Dose Equations for the Vagrant Shrew (Sorex vagrans)
Table 3-7. Toxicity Reference Values for Birds and Mammals
Table 3-8. Summary of Site-Specific LOAEL- and High SLV-based Risk-Based Concentrations
Table 3-9. Summary of Upland OU Human Health COCs and Risk Drivers
Table 3-10. Summary of Upland OU CECs and Risk Drivers
Table 4-1. Potential Federal ARARs and TBCs

Table 4-2. Potential Oregon State ARARs and TBCs
Table 4-3. Practical Quantitation Limits and Risk-Based Threshold Concentrations for Soil COCs and CECs.
Table 4-4. RAOs and Associated PRGs for Soil COCs and CECs
Table 5-1. General Response Actions, Technology Types, and Process Options Considered for Bradford Island Upland Operable Unit
Table 5-2. Effectiveness and Implementability Considerations
Table 5-3. Technology Screening Summary
Table 6-1. Identification of Hot Spots
Table 6-2. Assumed Concentrations for COCs in Backfill/Capping Material
Table 6-3. Toxicity Characteristic Leaching Procedure (TCLP) Maximum Values and Maximum Leachable Concentrations
Table 6-4. Landfill Alternative UCLs following Remedial Action
Table 6-5. Pistol Range Alternative UCLs following Remedial Action
Table 6-6. Estimated Present Value Costs for Landfill AOPC Alternatives
Table 6-7. Estimated Present Value Costs for Pistol Range AOPC Alternatives
Table 7-1. Landfill AOPC Alternatives Treatment of Hot Spots
Table 7-2. Landfill AOPC Remedial Alternative Estimated Residual Concentrations
Table 7-3. Pistol Range Remedial Alternative Estimated Residual Concentrations
Table 7-4. Landfill AOPC Criteria Comparison
Table 7-5. Pistol Range AOPC Criteria Comparison
Table 7-6. Landfill AOPC Relative Rating
Table 7-7. Pistol Range AOPC Relative Rating

Acronyms

AOPCs	Areas of Potential Concern
ARARs	Applicable or Relevant and Appropriate Requirements
AST	Above-ground Storage Tank
AWQC	Ambient Water Quality Criteria
BAF	Bioaccumulation Factor
BaPeq	benzo(a)pyrene-equivalent
BHC	benzene hexachloride
BHHRA	baseline human health risk assessment
BERA	baseline ecological risk assessment
bgs	below ground surface
BMPs	Best Management Practices
BW	Body Weight
CECs	Contaminants of Ecological Concern

CERCLA	Comprehensive Environmental Response, Compensation, Liability Act
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
COCs	Contaminants of Concern
COIs	Contaminants of Interest
COPCs	Contaminants of Potential Concern
cPAHs	carcinogenic polycyclic aromatic hydrocarbons
CPECs	Contaminants of Potential Ecological Concern
CSM	Conceptual Site Model
CTE	Central Tendency Exposure
CY	Cubic Yards
DEHP	bis(2-ethylhexyl) phthalate
DEQ	Department of Environmental Quality
DNOP	Di-n-octylphthalate
DoD	Department of Defense
Dw	dry weight
ECSI	Environmental Cleanup Site Information
EPA	United States Environmental Protection Agency
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESUs	Evolutionary Significant Units
◦F	Degrees Fahrenheit
FS	Feasibility Study
ft	feet
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMSA	Hazardous Material Storage Area
HPAH	High Molecular Weight polycyclic aromatic hydrocarbon
HQ	Hazard Quotient
H/V	slope (horizontal/vertical)
ICs	Institutional Controls
IEUBK	Integrated Exposure Uptake Biokinetic model
IRsoil	Ingestion Rate of Soil
LOAEL	Lowest Observable Adverse Effect Levels
LCF	loose cubic feet
LCY	loose cubic yards
LUC	Land Use Control
MDLs	Minimum Detection Limits
mg/kg	milligrams per kilogram

mg/L	milligrams per liter
MNA	Monitored Natural Attenuation
MP	Management Plan
MRLs	Minimum Reporting Limits
msl	Mean Sea Level
NCP	National Contingency Plan
NFA	No Further Action
NOAEL	No Observable Adverse Effect Levels
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
O & M	Operation and Maintenance
OAR	Oregon Administrative Rules
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
ORS	Oregon Revised Statutes
OU	Operable Unit
PA	Preliminary Assessment
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	perchloroethylene
PQL	Practical Quantitation Limit
PRGs	Preliminary Remediation Goals
QL	Quantitation/reporting Limit
RACERTM	Remedial Action Cost Engineering and Requirements
RAOs	Remedial Action Objectives
RBTCs	Risk-Based Threshold Concentrations
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RM	River Mile
RME	Reasonable Maximum Exposure
ROD	Record of Decision
SI	Site Inspection
SF	Square Feet
SLVs	Screening Level Values
SSI	Supplemental Site Investigation
SVE	Soil Vapor Extraction
SVOC	Semivolative Organic Compounds
TBC	To Be Considered
TCE	trichloroethylene

TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TPH	Total Petroleum Hydrocarbons
TRVs	Toxicity Reference Values
TSCA	Toxic Substances Control Act
UCL	Upper Confidence Limit
µg/dL	micrograms per deciliter
USACE	United States Army Corps of Engineers
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
VOC	Volatile Organic Compounds
VCP	Volunteer Cleanup Program
WDF	Washington Department of Fisheries

1 Introduction

1.1 Purpose of the Feasibility Study

The United States Army Corps of Engineers (USACE), as the lead federal agency for the CERCLA response at the Bradford Island Upland Operable Unit (OU), prepared this Feasibility Study (FS) in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended [42 U.S.C. 9601 et seq.], and the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) [40 CFR 300]. The FS process was in accordance with Executive Order 12580 and Engineering Regulation (ER) 200-2-3. The purpose of this Feasibility Study (FS) is to develop, screen, and evaluate remedial alternatives to address the risks posed by contaminants of concern (COCs) and contaminants of ecological concern (CECs) in the Upland Operable Unit (OU) of Bradford Island, located at the Bonneville Lock and Dam Project along the Columbia River in Oregon. This FS is based on the results of the Remedial Investigation [RI; URS 2012] and the Baseline Human Health and Ecological Risk Assessment (URS 2016).

The RI assembled and evaluated data to identify the nature and extent of contamination on Bradford Island and assessed current conditions on the Island, including initial screening of risks to human health and the environment. The Baseline Human Health and Ecological Risk Assessments concluded unacceptable levels of risk for human health due to the presence of carcinogenic polycyclic aromatic hydrocarbons (cPAHs) in the Landfill AOPC. The Risk Assessment also concluded unacceptable risk to ecological receptors due primarily to the presence of metals in the Landfill and Pistol Range AOPCs. In the FS, the results of the RI and the baseline risk assessments were used to identify remedial action objectives (RAOs), establish preliminary remediation goals (PRGs), develop remedial alternatives, and evaluate how effectively remedial alternatives achieve cleanup objectives. The FS lays the groundwork for selecting a remedial alternative that best manages risks to both human health and the environment.

1.2 The Feasibility Study Process

The FS process is outlined in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final* (USEPA 1988). The general steps and considerations in the FS process include:

Summarizing and synthesizing the results of the Remedial Investigation (RI), the baseline human health and ecological risk assessments, and related documents, as well as refining the physical conceptual site model for the Upland OU of Bradford Island

Developing RAOs that specify the COCs and CECs or risk driver contaminants, exposure pathways, and PRGs used to evaluate a range of remedial alternatives and to consider federal and state objectives for the site

Identifying applicable or relevant and appropriate requirements (ARARs) to comply with both state and federal regulations

Identifying general response actions for the site, including removal, disposal, containment, and treatment

Estimating the soil volumes or land areas to which the general response actions could be applied

Identifying and screening remedial technology types and specific process options best suited to achieve cleanup objectives for the RAOs

Assembling the technology types and process options into remedial alternatives specific for different areas of potential concern (AOPCs)

Completing a detailed evaluation and comparative analysis of the remedial alternatives that is consistent with CERCLA requirements

1.2.1 Regulatory Framework

The preliminary assessment/site inspection (SI) and RI phases have been completed for the study area. This FS makes / recommends risk management decisions. Risk management decisions are based on the site history, previous response actions, and comparisons of contaminant levels in the study area to chemical and risk based regulatory criteria. The FS identifies and evaluates remedial alternatives for achieving cleanup goals, and identifies ARARs.

The lead agency for the Bradford Island project is the U.S. Army Corps of Engineers (USACE), which will select the final remedy, including the final RAOs and cleanup levels. USACE is conducting the FS in accordance with CERCLA as authorized by Executive Order 12580. As such, the methodologies presented in this FS follow CERCLA process for developing and subsequently selecting a preferred remedial alternative. Bradford Island is located within State of Oregon boundaries and, as such, Oregon Department of Environmental Quality (ODEQ) ARARs and guidance are given primary consideration when incorporating state requirements. Given the proximity of the project to the State of Washington and potential impacts to resources within Washington, Ecology rules and guidance are also being evaluated and considered as appropriate. ODEQ and Washington State Department of Ecology (Ecology) are providing oversight and consultation with USACE as members of a Technical Advisory Group throughout the investigation, evaluation of site risks, and selection of a remedial alternative. Additional members of the Technical Advisory Group include federal, state, and tribal representatives. This group has been engaged by USACE throughout the RI and FS phases. While these members do not provide regulatory oversight to the project, they are given opportunities to provide technical input. Members of the Technical Advisory Group include:

- US EPA
- Bonneville Power Administration
- National Oceanic and Atmospheric Administration
- US Fish and Wildlife
- Yakama Nation
- Nez Perce Tribe
- Warm Springs Tribe
- Confederated Tribes of the Umatilla Indian Reservation
- Oregon Department of Environmental Quality
- Oregon Health Authority
- Washington Department of Ecology

- Washington Department of Health

1.2.2 Selecting a Final Remedy

Under CERCLA, USACE will present, evaluate, and compare remedial alternatives for a hazardous waste site in the FS. The final cleanup remedy will then be presented as a Proposed Plan for public review. After USACE has received and evaluated public comments on the Proposed Plan, the final remedy will be documented in the Record of Decision (ROD).

In selecting a final remedy USACE follows CERCLA evaluation processes, which include weighing the outcomes of evaluations using a number of criteria, including:

The nine CERCLA criteria provided in the National Contingency Plan (NCP) for evaluation of remedial alternatives

The statutory determination requirements in the NCP for selected remedies [40 CFR 300.430(f)(5)(ii)]

Risk management principles for sites with contaminated soils, as outlined in EPA guidance (USEPA 2005).

1.3 Definitions for the Feasibility Study

Definitions of regulatory terms, contaminant concentrations, spatial areas, and time frames used in the FS are provided below. For some of these terms USACE has site-specific definitions, but most are drawn directly from federal or state regulations or guidance documents. In the case of new, site-specific definitions, similar terms are referenced when applicable.

1.3.1 Regulatory Terms

Anthropogenic background is a CERCLA term that represents the concentrations of hazardous substances that are consistently present in the environment in the vicinity of the site as a result of human activities unrelated to releases from the site (USEPA 1997). When cleanup levels are less than anthropogenic background concentrations, it is recognized that anthropogenic background concentrations could result in recontamination of a site to levels that exceed cleanup levels. At the same time, EPA's remediation guidance (USEPA 2005) states that cleanup levels will normally not be set below natural or anthropogenic background concentrations. Therefore, portions of the cleanup action may be delayed until off-site sources of hazardous substances are controlled, which reduces the likelihood of such recontamination.

Cleanup level under CERCLA means the concentration of a hazardous substance in an environmental medium and under specified exposure conditions that is determined to be protective of human health and the environment. Cleanup levels are proposed in the FS but are not finalized until the ROD.

Contaminants of potential concern (COPCs)/Contaminants of concern (COCs) are two related terms used in the baseline human health risk assessment. The COPCs are initially identified through a conservative risk-based screening process. In this process, contaminant concentrations in soil, soil gas, and groundwater are compared to conservative risk-based screening levels or effects standards. Being conservative means that contaminants are more often included than excluded from the screening process — meant to ensure chemicals that may pose unacceptable risk are not erroneously eliminated or 'missed' during the preliminary screening process. In later stages, more precise comparisons are made to determine if such potential contaminants are posing risks to humans or the environment. In this process, contaminants that are present in any samples at concentrations above the screening levels are identified as "contaminants of potential concern," which then undergo further analysis in the baseline risk assessments. Baseline risk assessments consider the distribution of COPCs in all of the media and determine if they exceed acceptable risk levels. The COCs represent a defined subset of the COPCs that exceed these acceptable risk levels. COPCs and COCs are specific to human health risk, whereas **contaminants of potential ecological concern (CPECs)/contaminants are ecological concern (CECs)** are specific to ecological risk, but are differentiated through a similar process of determining acceptable risk levels.

Natural background represents the concentrations of hazardous substances that are consistently present in an environment that has not been influenced by localized human activities, but may have been influenced by regional or global human activities. The definition includes substances such as metals that are found naturally in bedrock, soils, and sediments, as well as persistent organic compounds such as polycyclic aromatic hydrocarbons (PAHs) that can be found in soil and sediments throughout the state because of global distribution of these contaminants.

Point of compliance is defined as the point or points where cleanup levels shall be achieved. These are physical places as opposed to points in time or regulatory concepts.

Quantitation/reporting limit (QL) is defined as the lowest concentration that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions using department (USEPA) approved methods. The terms practical quantitation limit (PQL) and reporting limit are synonymous with quantitation limit.

Preliminary remediation goals (PRGs) are specific desired contaminant endpoint concentrations, or risk levels for each exposure pathway, that are believed to provide adequate protection of human health and the environment based on available site information (USEPA 1997). For the FS, PRGs are expressed as medium-specific concentrations for the contaminants that present the principal risks (i.e., the risk drivers). PRGs are based on consideration of the following factors:

ARARs

Risk-based threshold concentrations (RBTCs) developed in the risk assessments

Natural background concentrations that are used to develop PRGs if protective RBTCs are below background concentrations.

Analytical PQLs which are used if protective RBTCs are below concentrations that can be quantified by chemical analysis.

PRGs are presented in the FS as the proposed cleanup levels; cleanup levels will be finalized after the FS.

Remedial action objectives (RAOs) describe what the proposed remedial action is expected to accomplish (USEPA 1999). They are narrative statements of the medium-specific or area-specific goals for protecting human health and the environment. RAOs are used to help focus development and evaluation of remedial alternatives. RAOs are derived from the baseline risk assessments and are based on the exposure pathways and receptors, and the identified COCs.

Risk drivers are used in the FS to indicate the subset of COCs and CECs identified in the baseline risk assessments that present the principal risks.[1] For this report, principal risk refers to COCs or CECs with a Hazard Quotient (HQ) greater than 1 or a lifetime excess cancer risk greater than $1x10^{-4}$, the high end of EPA's Risk Management Range of $1x10^{-4}$ to $1x10^{-6}$. Risk management is also applied when identifying risk drivers, taking into account issues such as land use and uncertainty. For other COCs and CECs not designated as risk drivers, the estimated potential for risk reduction associated with those contaminants once remedial actions are completed is discussed in the FS. In addition, COCs and CECs may be assessed as part of the reviews that are conducted every five years once a CERCLA cleanup has begun (five-year reviews), and they may be included in the post-cleanup monitoring program.

1.3.2 Soil Concentration Terms

Point concentrations are contaminant concentrations in soils at a given sampling location, where each value is given equal weight.

A **Risk-based threshold concentration (RBTC)** is the concentration of a contaminant in soils estimated to be protective of a particular receptor for a certain exposure pathway and target risk level. Any concentration above the threshold is considered not protective. RBTCs are calculated based on the baseline risk assessments and were derived as part of the risk assessment and presented in the risk assessment report. Soil RBTCs are used along with other site information to set PRGs (defined above) in the FS.

95% upper confidence limit on the mean (95% UCL) is a statistically derived quantity associated with a representative sample from a population (e.g., contaminant concentrations in soil samples taken from a site) such that 95% of the time, the true average of the population (from which the sample was taken) will be less than the 95 UCL quantity statistically derived from the samples. That is, 95% of the time the true average soil contaminant concentration, if known, would be less than the 95 UCL that is based on contaminant concentrations found in a corresponding set of soil samples. The 95 UCL is used to account for uncertainty in contaminant concentrations (that is, we don't know the actual average of contaminant concentrations in the soil, so we are estimating it based on sample results) in a way that ensures actual contaminant concentrations are not underestimated.

1.3.3 Terms for Spatial Areas

Definitions of relevant spatial areas used in the RI/FS process are provided below.

An **area of potential concern (AOPC)** represents the areal extent of soils that present unacceptable risks and will likely require use of active or passive remedial technologies. The AOPC footprints are delineated using soil PRGs and other applicable risk information (e.g.,

---

1 This approach has been used in several RODs for cleanup under CERCLA, including the Anaconda, MT Superfund site, Operable Unit 4 (USEPA 1998); Wyckoff Co./Eagle Harbor (USEPA 2000 EPA Superfund Record of Decision: Wyckoff); and Puget Sound Naval Shipyard Complex (USEPA 2000 EPA Superfund Record of Decision: Puget Sound).

current or future exposure pathways). Soil management method(s) considered for use within AOPCs will be compatible with the physical, chemical, biological, and engineering factors present (USEPA 1988).

Site is frequently used in this FS to refer to only the Upland OU (soil portion of Bradford Island), and not to the River OU (in-water portion of the Columbia River adjacent to the Island).

1.3.4 Terms Related to Time Frames

The remedial alternatives refer to different time frames when describing different aspects of the remedy, such as the number of years to design or implement a remedy, or the number of years to achieve the cleanup levels. For clarity, the terms and time frames used in the FS are defined below.

Construction period is the time assumed necessary to construct a remedial alternative.

Time to achieve cleanup levels is most readily defined as the time from the start of remedial construction to when PRGs are achieved. In cases where a PRG is unlikely to be achieved due to technical impracticability (e.g., if the PRG is based on natural background), cleanup levels are as close as practicable to the PRGs, and the time to achieve such levels is estimated while no attempt is made to estimate the time to achieve impracticable PRGs.

1.4 Document Organization

The remainder of this document is organized as follows:

Section 2 (Site Setting, RI Summary, and Current Conditions) builds on the key findings of the RI and focuses on the site characteristics that affect the development of AOPCs, selection of representative technologies, and assembly of alternatives. The FS dataset is also summarized in this section.

Section 3 (Risk Assessment Summary) presents the results of the baseline human health and ecological risk assessments and the RBTCs for risk drivers.

Section 4 (Remedial Action Objectives and Preliminary Remediation Goals) presents the recommended RAOs and ARARs, and identifies PRGs for the FS.

Section 5 (Identification and Screening of Remedial Technologies) presents the results of screening a broad array of remedial approaches and identifies representative technologies that may be applied to the AOPCs.

Section 6 (Development of Remedial Alternatives) describes site-wide remedial alternatives designed to achieve the RAOs, based on the AOPC footprints and representative technologies.

Section 7 (Detailed Analysis of Alternatives) presents results of screening the remedial alternatives individually using CERCLA guidance. The risk reduction achieved by each remedy is also discussed. This section also includes a comparison of the remedial alternatives on the basis of CERCLA evaluation criteria.

Tables and figures appear at the end of the report. Details that support various analyses in the FS are presented in the appendices.

1.5 References

URS (URS Corporation). 2012. Upland and River Operable Units Remedial Investigation Report, Bradford Island, Cascade Locks, Oregon.

URS. 2016. Baseline Human Health and Ecological Risk Assessment, Upland Operable Unit.

USEPA (United States Environmental Protection Agency). 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final. EPA/540/G-89/004.

USEPA. 1997. EPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund. EPA 910-R-97-005.

USEPA. 1998. Record of Decision, Anaconda Co. Smelter, Anaconda, Montana. EPA/541/R-98/096.

USEPA. 1999. Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilites, Peer Review Draft. Office of Solid Waste and Emergency Response. USEPA530-D-99-001A.

USEPA. 2000. EPA Superfund Record of Decision: Puget Sound Naval Shipyard Complex, EPA/ROD/R10-00/516.

USEPA. 2000. EPA Superfund Record of Decision: Wyckoff Co./Eagle Harbor, Bainbridge Island, WA.

USEPA. 2005. Guidance for Developing Ecological Soil Screening Levels-Revised, OSWER Directive 9285.7-55.

2 Site Setting, RI Summary, and Current Conditions

2.1 Environmental Setting

2.1.1 General Location and Description

The Bonneville Lock and Dam Project (the Project) is the most downstream dam within the Columbia-Snake River navigation system that consists of eight locks and dams, along with three additional dams that do not have locks. The Bonneville Dam is at the upper limit of tidal influence from the Pacific Ocean, about 145 miles upstream from the mouth of the Columbia River and 40 miles east of the cities of Portland, Oregon and Vancouver, Washington that border opposite sides of the Columbia River (Portland-Vancouver). The dam is located at 45° 38′ 27′′ N - 121° 56′ 31′′ W. Bonneville Lock and Dam creates a 48- mile-long reservoir from the Bonneville Dam upstream to the Dalles Dam, called the Bonneville Pool. The Columbia River at the Bonneville Dam is divided into three channels by two islands: Bradford Island and Cascade Island. A third island, Robins Island, located between the Oregon shore and Bradford Island, serves as the southern terminus for the First Powerhouse (Figure 2-1), and is an island only by virtue of the navigation channel (second lock) excavated between the Oregon shore and what is now Robins Island. The tailrace for the First Powerhouse forms one channel, the spillway forms the middle channel, and the tailrace channel for the Second Powerhouse forms the third channel. The spillway, consisting of 18 gates, each 50 feet wide, is located between Bradford and Cascade Islands, spanning the middle channel. The spill gates are raised to allow excess river flow to pass under them at a depth of about 50 feet below the upstream water surface. (The spill gates are only opened when the pool has filled to a certain extent [and other specifications apply]; in those conditions, the water surface is about 50 feet above the bottom of the spill gates.)

The major features of the Project (Figure 2-1) include the spillway, two powerhouses, two fish ladders, two navigation locks (the first lock is no longer in use), and the Project fish hatchery (there is also a second fish hatchery immediately upstream of the Project operated by US Fish and Wildlife Service). The Project fish hatchery, main office, and navigation lock visitor center are located on the Oregon shore of the Columbia River. A warehouse and automotive garage facility, and navigation lock support facilities, are located on Robins Island. The major features on Bradford Island are the Bradford Island visitor center, fish ladders, the service center building, and the equipment building. The sandblast building was structurally damaged in a storm several years ago and was demolished in 2012. Another fish ladder is located on Cascade Island, and a third visitor center is located on the north shore of the Columbia River in Washington State.

The authorized federal navigation channel in this reach of the river is 300 feet wide and 27 feet deep, although the depth is currently maintained at 17 feet (USACE, 1991). Limited dredging is necessary to keep the channel to the maintained depth near the dam. Bathymetric surveys conducted by USACE indicate that the pool near the Bonneville Dam (within the spillway forebay) is up to 100 feet deep.

2.1.2 Site History

2.1.2.1 First Powerhouse and Original Lock

Construction of the First Powerhouse and navigation lock, spillway, fish passage facilities, fish hatchery, and office and maintenance buildings began in 1933. Operations at the Bonneville Dam complex began in 1938. During World War II, in addition to enlarging the first powerhouse and installing additional generators, the military installed anti-aircraft batteries and a rifle/pistol range near the present-day location of the service center (URS, 2012). The firing range was eventually used only for small arms and became known as the pistol range.

2.1.2.2 Second Powerhouse

Between 1974 and 1981, the Second Powerhouse was constructed adjacent to the Washington State shore, to aid in supplying the electrical power needs of the Northwest. The construction of the Second Powerhouse required the relocation of the former town site of North Bonneville, which was relocated approximately 1.5 miles downstream. In addition, portions of Washington Highway 14 and Burlington Northern railroad track were also relocated to accommodate construction of the Second Powerhouse. During the roadway/railway construction activities, a significant archeological site was excavated. First noted in the Lewis and Clark journals, the site is the only known relatively undisturbed archeological site along the lower Columbia River and provided evidence of 500 years of occupation from the time of Native American occupation to the time of historic settlement in the mid-1800s. This site is on the National Register of Historic Places. Retrieval of cultural material necessary for site interpretation began when it was realized that construction activities would affect the archeological site. Retrieval of cultural material was completed in the summer of 1979 (URS, 2012).

2.1.2.3 Second Lock

A second navigation lock (Figure 2-1) was constructed at the Bonneville Power Complex on the Oregon side between 1989 and 1993. Associated with construction of the new lock, the southeastern edge of Bradford Island was excavated to improve the approach channel. Soils from that excavation were placed to create Goose Island, 0.5 mile upstream near the Oregon shore.

2.1.2.4 Discontinued Operations

The old navigation lock adjacent to the First Powerhouse is no longer in use. The upstream side of the old navigation lock consists of an end sill (where lock gates are located) that extends from the riverbed to an elevation of 40 feet above mean sea level (msl). The upstream approach for the current navigation lock is located immediately south of the upstream approach for the old navigation lock and has an end sill that extends to an elevation of 51 feet above msl.

2.1.2.5 Current Facility Operations

The U.S. Army Corps of Engineers (USACE) operates and maintains Bonneville Lock and Dam for hydropower, navigation, recreation, and natural resource and wildlife preservation.

2.1.2.6 Bonneville Project Regulatory History

Bonneville Lock and Dam

The Bonneville Lock and Dam was initially placed on the Federal Facilities Compliance Docket after the 1986 explosive failure of a bushing on an oil circuit breaker in the switchyard on the roof of the First Powerhouse. The bushing failure released approximately one pound of PCBs in tar from the core of the bushing. The bulk of the tar fell on the powerhouse roof, but an unknown quantity reached the river. A second bushing failed in 1991 with similar results. Both spills were cleaned up in accordance with the Toxic Substances Control Act (TSCA) and documented in a preliminary assessment (PA) in 1992. In 1994, the EPA declared No Further Action (NFA) was necessary with respect to these accidental releases. All PCB-containing bushings and circuit breakers on the powerhouse roof were replaced in the 1995 rehabilitation of the powerhouse.

Hamilton Island

In 1987, Hamilton Island, a former construction landfill on project lands downstream from the Second Powerhouse in Washington State, was placed on the Federal Facilities Compliance Docket. The site was investigated for wastes from the construction of the Second Powerhouse at Bonneville Dam, possible PCB waste from the Bonneville project, and wastes from demolition of North Bonneville. In 1991 the site was placed on the National Priorities List (NPL) under the CERCLA. USACE completed a RI/FS in 1994 and the site was delisted by EPA in 1995 after a NFA ROD. This location is not discussed further in this document.

Bradford Island

On June 13, 1996, USACE submitted a letter to EPA Region 10 and ODEQ, informing them of the presence of the Bradford Island Landfill. The Landfill is a former waste disposal site at the Bonneville Lock and Dam Project occupying the northeastern portion of Bradford Island. The Landfill was used from the early 1940s until the early 1980s. The half-acre Landfill area is adjacent to portions of the island used as a shooting range and as disposal areas for sandblast grit and light bulbs; these have since been identified as three separate AOPCs. Following the letter, a need was identified to collect sediment samples in the Columbia River around the perimeter of the island, along with collection of groundwater seep samples if seeps were identified. These issues were considered during an initial site investigation (the 1998 SI) related to ODEQ's Voluntary Cleanup Program (VCP). A timeline of activities at Bradford Island is provided below.

Bradford Island was added to the ODEQ Environmental Cleanup Site Information (ECSI) database on April 1, 1997.

On April 24, 1997, the Bonneville Lock and Dam Project signed a Letter of Intent to participate in ODEQ's VCP for the investigation and remediation of the site.

On February 18, 1998, the USACE Portland District Engineer signed an ODEQ Voluntary Cleanup Agreement letter for the site.

In 2004, USACE elected to continue the Bradford Island project under CERCLA and also in accordance with USACE Engineering Regulation (ER) 200-2-3, *Environmental Compliance Policies*.

USACE completed the RI report in 2012 (URS, 2012) and is completing the FS in accordance with CERCLA principles, with ODEQ requirements as applicable, and with consideration of ARARs. Members of the Technical Advisory Group have been provided the opportunity to comment and participate in the RI/FS process.

USACE maintains a National Pollutant Discharge Elimination System (NPDES) point source discharge permit for discharges from the Project's wastewater treatment plant. The plant services all sanitary waste facilities on the Project. Discharges from the Project fish hatchery are not treated by this facility but have a separate discharge in Tanner Creek managed by the Oregon Department of Fish and Wildlife (ODFW).

2.1.3 Geology, Climate, Hydrogeology, and Hydrology

2.1.3.1 Regional Geology

The Project is located in the Columbia River Gorge, a 50-mile canyon that cuts through the Cascade Range physiographic province (Orr & Orr, 1999). The canyon has formed through time as the Columbia River incised through various geologic formations, including the Western Cascade Group, the Columbia River Basalt Group, and the High Cascade Group, in response to the uplift of the Cascades over the last 2 million years (Beeson & Tolan, 1987).

Three bedrock formations are present near Bonneville project: the Ohanapecosh Formation (also referred to as the Weigle Formation), the Eagle Creek Formation, and the Columbia River Basalt Group (Holdredge, 1937) (Wise, 1970). The Ohanapecosh Formation consists of late Oligocene-aged volcaniclastic siltstones and sandstones with minor conglomerates. As much as two-thirds of the clasts in this formation consist of glass fragments. The fragments have subsequently altered to a dominantly clay mineral assemblage, greatly weakening the formation.

Folding and faulting have significantly disturbed the Ohanapecosh Formation. Bedding generally strikes northeast and north, with a dip of 5 to 20 degrees to the east and southeast. Two predominant fault/shear zone orientations have been identified in association with the development and construction of Bonneville Dam. They include northwest-striking features dipping moderately to steeply to the northeast and northeast-striking features dipping gently to moderately to the northwest. These features do not continue into the overlying Eagle Creek Formation, indicating that fault movement ceased before the Eagle Creek sediments were deposited. No outcrops of the Ohanapecosh formation are found at the site.

The Eagle Creek Formation overlies the Ohanapecosh Formation, and is differentiated primarily by larger clast size and lack of alteration. The Eagle Creek Formation consists primarily of sandstones and conglomerates, with individual units of sedimentary tuffs. Bedding in the unit is near horizontal. The Eagle Creek Formation crops out near river level near the site.

The Columbia River Basalt Group disconformably overlies the Eagle Creek Formation. Flood basalts of this group are Miocene in age and originated from a series of fissures in eastern Washington, Oregon, and Idaho. In the vicinity of Bonneville Dam, the basalts have been uplifted several hundred feet above the current river level.

Two landslides have significantly modified the topography in the vicinity of the site (Sager, 1989). Those slides are believed to have been at least partly the result of catastrophic floods during the late Pleistocene that scoured away the talus slopes from the Columbia Gorge. That action over-steepened the walls of the Gorge and effectively removed the buttressing effect of the talus slopes. Scouring also exposed the clay-rich Ohanapecosh Formation, which may have contributed to the landslides. The Tooth Rock Landslide is a large rotational block failure that originated on the Oregon side of the Gorge, south of Bradford Island. The slide is reported to have incurred only rotational movement, without lateral expansion. Large slide blocks of the Eagle Creek Formation contributed to the formation of Bradford Island. Because of the slide's rotational nature, the blocks are relatively undisturbed and form a local, but variable, bedrock surface beneath the Bradford Island. Portions of the Tooth Rock slide block extend into the Columbia River and are submerged. Therefore, the river bottom in the immediate vicinity of Bradford Island consists of Eagle Creek Formation overlain by a thin layer of sands and silts that have been deposited in lower velocity areas.

A second large-scale landslide in the area is known as the Bonneville (or Cascade) slide. The slide originated on the Washington side of the Gorge between 400 and 800 years ago. The toe of the landslide forms the northern abutment of the Second Powerhouse. Debris from the slide has been observed to overlie the Tooth Rock slide on portions of Bradford Island. The Tooth Rock slide blocks at the site are also overlain by up to 30 feet of alluvium associated with Holocene to recent flooding of the Columbia River. The alluvium consists of silty sands and gravels that contain increasing amounts of Eagle Creek Formation clasts with depth.

2.1.3.2 Climate

A meteorological observation station has been in operation at the Project since July 1, 1948. During a 57-year period of meteorological records (1948 through 2005), the station recorded average summer daytime maximum temperatures of 65.8 degrees Fahrenheit (°F) and average winter daytime maximum temperatures of 35.4 °F (Western Regional Climate Center 2002). Temperature extremes at the Bonneville Dam have varied from a low of -5 °F on January 31, 1950, to a high of 107 °F on August 18, 1977.

The average annual precipitation at the Project for the period of record is 77.05 inches. December and January are the months with the highest precipitation rates, and July is the month with the lowest (Western Regional Climate Center, 2002). Recorded daily maximum precipitation rates have exceeded 1 inch for every month, with the maximum daily rate of 5.05 inches recorded on November 25, 1999. Average annual snowfall at the dam is 17.7 inches, normally occurring from November through March.

2.1.3.3 Groundwater/Hydrogeology

Occurrences of shallow groundwater were evaluated as part of environmental investigations near the former landfill and the former sandblast building (eastern end of Bradford Island) (URS, 2012). Based on these investigations, two shallow stratigraphic units exist on the eastern end of Bradford Island:

1. **Fill/alluvium**. This unit consists of silty to clayey sands and ranges from 15 to 30 feet in thickness. At depth, there are increasing bedrock clasts. This unit occurs beneath the upland portion of the site and pinches out near the northern shore of Bradford Island.

2. **Bedrock**. The bedrock unit consists of a slide block emplaced from the Oregon side of the river. The block is composed of the Eagle Creek Formation, which consists primarily of sandstones and conglomerates. The uppermost 2 to 5 feet of this unit is fractured.

Groundwater on the eastern end of Bradford Island appears to be perched in the alluvium above the less-permeable Eagle Creek slide block. Where the fractured bedrock crops out on the north shore of the island, seeps form in the winter months. The slide block forms the base of the river near the island, with no to little sediment thickness found on top of the slide block.

Based on the horizontal hydraulic gradient measured in the fill/alluvium, the direction of groundwater flow beneath the Landfill AOPC is to the north. At the Sandblast Area AOPC, groundwater flow is to the north and northwest.

Additional discussion of groundwater as a potential transport mechanism for contaminants is discussed in Section 2.4.6

Drinking Water - Bonneville Lock and Dam Project

No active drinking water wells are located on Bradford Island. Water supply well DW2, which is located on the eastern side of Bradford Island, was used for drinking water until 2000 and was decommissioned in 2008.

Hatchery Wells H1, H2a, H3, H4, H5, H6 and H7 are located on the western end of Robins Island (Figure 2-1). The hatchery wells were installed between 1986 and 1991 to replace wells that were abandoned during the construction of the new navigation lock. The groundwater is extracted from a former alluvial unit that was buried by the Tooth Rock landslide. The alluvium overlies the Ohanapecosh Formation in this location and is up to 100 feet thick (Scofield 1998). These wells provide water to the hatchery and, either individually or combined, also provide drinking water to the Project. Water supply wells DW1 (also referred to as PW1 and WW-1794) and DW5 (also referred to as PW2 and WW-1800) are located on the western end of Robins Island (Figure 2-1). Both DW1 and DW5 historically provided drinking water to the Project. USACE stopped using wells DW1 and DW5 several years ago for drinking water as the wells were going dry; however, USACE has not yet decommissioned the wells.

Water supply wells DW3 and DW4, which are located on Cascade Island and the Washington shore, respectively, are currently supplying drinking water to the Project. Potential releases to groundwater from Bradford Island do not pose a threat to these populations due to the lack of hydraulic connection to the perched water-bearing unit beneath the island.

Drinking Water – Project Vicinity

The population within a 4-mile radius relies on municipal water supplies taken from groundwater supply wells. The Columbia River hydraulically separates these populations from Bradford, Cascade, and Robins Islands. Potential releases to groundwater from Bradford Island do not pose a threat to these populations due to the lack of hydraulic connection to the perched water-bearing unit beneath the island.

2.1.3.4 River Hydrology

Flow within the Columbia River is modified by the operations of several federal and non-federal dams. Bonneville Dam at river mile (RM) 146.1 is the dam farthest downstream on the Columbia River. Hydrologic conditions immediately upstream and downstream of the dam are the primary focus of this section; however, regional hydrology is addressed given its influence on local hydrologic processes and the Columbia River's evolution.

Regional Hydrology

The Columbia River drains an area of 259,000 square miles and is ranked seventh in length and fourth in stream flow among United States rivers. It flows 1,243 miles from its headwaters in the Canadian Rockies of British Columbia, across Washington State, and along the border of Washington and Oregon to the Pacific Ocean (Figure 2-2). There are 11 dams, eight of which include navigation locks, on the Columbia River's mainstem in the United States, and 162 dams within the river's entire drainage basin that form reservoirs with capacities greater than 5,000 acre-feet (USGS, 1996).

Climate in the Columbia River Basin varies considerably, but river hydrology is dominated by snowmelt from high-elevation areas, with the majority of annual flow occurring between April and July. High flows also occur between November and March, caused by heavy winter precipitation (NPCC, 2004).

All of the major dams and reservoirs within the basin are operated in coordination with each other to manage floods, control fish migration, and produce power. The general operating year for the dams and reservoirs within the basin is divided into three periods:

September through December – A fixed reservoir drawdown occurs, since a forecasted volume of runoff that will occur in the spring is not yet available. Flows are managed to enhance the spawning of chum salmon below Bonneville Dam.

January through mid-March or April – A variable drawdown occurs to meet the forecasted volume of the spring runoff based on snowpack measurements. Water must be present in April for juvenile fish migration.

April through August – Refill season; the reservoirs are managed in an effort to fill the reservoirs and allow fish migration.

Local Hydrology

Most technical publications concerning the Columbia River focus on the basin and subbasins, specifically as they relate to water quality and specific habitats. Publications addressing details of individual hydrologic inputs in the immediate vicinity of Bonneville Dam do not appear to be readily available. The position of the Columbia River as a border between Oregon and Washington may contribute to the disjunction of available information. A series of subbasin plans and water quality reports were reviewed to obtain general information about the Columbia River Basin within the area of interest, which runs approximately from RM 142 (Pierce and Ives Islands) to RM 148 (Bridge of the Gods).

Bonneville Dam, along with most dams on the Columbia River, is considered a run-of-river project. Run-of-river projects, by definition, have limited storage and were developed primarily for navigation and hydropower. These types of projects pass water at the dam at nearly the same rate it enters the reservoir, with an average variance of water level behind the dam of 3 to 5 feet. The normal operation range for the pool behind Bonneville Dam is between 71.5 and 76.6 ft mean sea level (msl), as measured at the dam. The tailwater elevation below Bonneville Dam varies in direct relationship to the river discharges, and ranges from about 7.0 feet above mslat a river flow of 70,000 cubic feet per second (cfs) to 36.3 feet above msl at a river flow of 660,000 cfs (USACE, 1998). The tailwater elevation is also influenced by tidal variation. From Bonneville Dam to the ocean, the slope of the Columbia River is very flat and subject to tidal action. The daily tidal influence on water level during low water periods ranges from 1 to 2 feet at the dam (Washington Department of Fisheries et al. 1990). Within the Columbia River Basin are numerous subbasins formed by tributaries of the mainstem river. Although the layouts of the subbasins in their entirety extend beyond the area of interest, they each contain tributaries of the Columbia, as identified below, within the area of interest.

Hydrologic inputs immediately upstream of the dam include Ruckel and Eagle Creeks on the Oregon side. Washington maps do not indicate any named creeks immediately above the dam, although drainage features are presumed to exist. Hydrologic inputs immediately downstream of the dam include Tanner and Moffett Creeks on the Oregon side with Greenleaf and Hamilton Creeks contributing on the Washington side.

Streams draining the Oregon side of the Columbia River Basin (within the area of interest) originate and flow through the Hatfield Wilderness, a 39,000-acre portion of land managed by the United States Forest Service (USFS). Although streams discharging to the Columbia originate and primarily flow through the protected wilderness, they also pass through the privately held and often developed properties located along the waterfront. Development such as roadways and railroads with riprap bisect the lower reaches of the tributaries and are presumed to have the greatest influence on the flow rate and water quality at the point where the tributaries join the Columbia.

Urbanization of the land along the Columbia on the Washington side has substantially altered original drainage and subsequent hydrologic inputs. A major highway, railroad, and associated riprap also bisect tributaries along the riverfront on the Washington side.

Forestry is a major industry upstream and downstream of the dam, especially in Washington. Timber practices are typically clear-cut and slash-and-burn, subject to Forest Practices Act regulations of both states (WDF et al., 1990). The significance of the forestry industry, and to a lesser degree agriculture, is its effect on runoff and subsequent water quality. A damaged or destroyed riparian buffer can substantially alter the morphology of streambeds and, in some cases, whole drainage basins. An example would be increased flow rates, which can result in aggressive streambed scour, increased turbidity, elevated concentrations of dissolved minerals, and habitat destruction. Not only is the tributary being affected but also subsequent discharge can potentially influence water quality, habitat, and flow in the mainstem.

2.1.4 Ecological Habitats and Biological Communities

2.1.4.1 Ecological Habitats

For ecological concerns, there are four areas of potential concern, as described below: Landfill AOPC, Sandblast AOPC, Pistol Range AOPC, and Bulb Slope AOPC.

Landfill AOPC

Upland meadow and shrub/forest fringe communities occupy the Landfill AOPC (Figure 2-3). This area once served as a temporary nursery for landscape plants used at Bonneville Dam and adjacent facilities. Not all of these ornamental plants were removed and some have survived. Adjacent to the Landfill AOPC is a larger area of conifer-dominated forest. The upland meadow habitat that occupies the surface of the Landfill AOPC has been disturbed by various field investigative activities (i.e., test pits, drilling operations) but has since been recolonized by surrounding vegetation.

The shrub and forest fringe area is characterized by rocky outcrops at the edges of the island and at the margin of the flat meadow area adjacent to the forested habitat. The substrate consists of a mixture of soils, rock that may have been placed, and what appear to be natural rock outcrops. The Landfill AOPC terrain is flat at the top and slopes steeply to the north and east into the Columbia River. The slopes are more densely vegetated with shrubs and trees than the flatter areas adjacent to the meadow.

The conifer forest in the Upland OU Reference Area appears to be the least disturbed habitat on the island, as it is composed of mostly native species. This forest is apparently relatively young; USACE photographs from the 1930s show much smaller trees. It is likely that this forest was naturally seeded rather than planted. No stumps are present, indicating that past logging either did not occur, or was followed by recontouring the land that included removal of stumps. The larger trees are up to 1.5 feet in diameter at breast height (DBH), and form a closed canopy. The substrate in the forest area consists of relatively thin topsoil and rocky outcrops. Dead and downed woody material is common.

Sandblast Area AOPC

The Sandblast Area AOPC generally consists of a north facing slope with numerous topographic/habitat complexities (see Figure 2-3). Upslope of the former sandblast building is a relatively undisturbed and densely vegetated hill slope. Below the upper hill slope is a relatively flat and paved area around the former sandblast building. Downslope (to the north-northeast) of the former sandblast building and the adjacent paved area is a short, steep hill with a shrub/forest community leading to the flat, unvegetated equipment laydown area and the paved road leading east to the Landfill AOPC. To the northwest of the former sandblast building is a relatively flat, herbaceously vegetated area, followed by a recently disturbed slope, then a paved road. Excavation and filling activities on the northwest slope in 2009 removed vegetation and exposed bare, erodible soils at the ground surface. During the following year, the disturbed area naturally revegetated and is currently vegetated with a dense scrub-shrub community.

Pistol Range AOPC

Once the Pistol Range AOPC ceased being used for small arms practice in the late 1960s or early 1970s, the firing range was recolonized by surrounding herbaceous vegetation (Figure 2-3). The topography of the area consists of a series of cuts and fills, resulting in a sequence of slopes and flat areas. Currently, the ground surface is vegetated with a mix of scrub-shrub and herbaceous vegetation. An upland meadow community, similar to the Landfill AOPC meadow community, covers the former firing range. The hillside behind the backstop is moderately steep (15 to 30 degree slopes) and is densely vegetated with herbaceous vegetation and shrub/forest fringe communities. Along the southern portion of the former firing range and south of the access road, a densely vegetated scrub-shrub community is present.

Bulb Slope AOPC

The Bulb Slope AOPC, so named because of historical disposal of light bulbs, including incandescent, fluorescent and mercury vapor lamps in the area, consists of a steeply sloped area between the Landfill access road and the Columbia River on the north side of Bradford Island (see Figure 2-3). The substrate consists of a mixture of soils, rock that may have been placed, and what appear to be natural rock outcrops, all of which is underlain by siltstone bedrock. The majority of the Bulb Slope AOPC is vegetated and/or covered with organic debris.

2.1.4.2 Biological Communities

ESA-Listed Species and Other Important Fish

The list of sensitive species with potential to occur at the Bonneville Dam Forebay (the Forebay) is provided in Table 2-1. The list of species was originally derived from correspondence with multiple agencies and stakeholders, reference books, and reports of studies focused on protected species in the Bonneville Dam vicinity. For more information regarding the list of species see RI report Section 3 (URS, 2012). The list is focused on protected species in the Bonneville Dam vicinity. The status of the species in the list was updated based on the Threatened, Endangered, and Candidate Fish and Wildlife Species in Oregon (USFWS, 2014) (ODFW, 2014) and the Oregon Biodiversity Information Center Rare, Threatened and Endangered Species of Oregon list (Center, 2014).

The special-status (federally and state-listed threatened) fish and wildlife species that are known to occur or could potentially occur at the site are described below. In addition, this section also presents a brief discussion of non-listed important fish species that may occur in the Forebay.

2.1.4.2.1.1 Fish Species

The Lower Columbia River is characterized by warmer, slower waters than the upper reaches, and this region consequently supports a larger diversity of native resident fish species such as the following non-listed fish: white sturgeon (*Acipescer transmontanus*), longnose suckers (*Catostomus catostomus*), and minnows (i.e., chiselmouth [*Acrocheilus alutaceus*]). Other native species that are found throughout the Columbia River include special-status trout (i.e., steelhead [*Oncorhynchus* spp.] and bull trout [*Salvelinus confluentus*]), non-listed trout (i.e., cutthroat trout [*Oncorhynchus clarki clarki*]), non-listed whitefish (i.e., mountain whitefish [*Prosopium williamsoni*]), and a variety of non-listed sculpins (*Cottidae*) (Troffe, 1999) (USACE, 2001). Special-status anadromous fish species that have the potential to be present in the Bonneville Forebay are listed Table 2-2. The Bonneville Hatchery, located just below the dam, raises chinook (*Oncorhynchus tshawytscha*) and coho salmon (*Oncorhynchus kisutch*)Ten of the 12 evolutionarily significant units (ESUs) shown in Table 2-2 have the potential to be present near Bradford Island as juveniles, adults, or both. The Columbia River near Bradford Island is used by these species primarily as a migratory route between upstream spawning areas and the Pacific Ocean. The listed ESUs fall into two juvenile life-history strategies: "ocean-type" that rear in freshwater for only a few weeks to a few months before migrating to the estuary/ocean during their first year of life, and "stream-type" that spend at least a year rearing in freshwater prior to their downstream migration to the ocean. The Biological Assessment for Anadromous Fish Species and Steller Sea Lion Essential Fish Habitat (USACE, 2007) provides additional information as well as a general overview of the life history and status of each ESU and describes when adults and juveniles would be expected to be present near Bradford Island.

Adult salmon typically nearly cease feeding once leaving the Columbia River estuary on their upstream migration. Adult steelhead migrating upstream feed to a limited extent. Juvenile salmon and steelhead feed on their downstream migration. Juveniles feed on aquatic invertebrates and small fish. As noted above, several listed and candidate anadromous fish pass through the lower Columbia River on their journeys between spawning areas and the ocean. The residence time for anadromous fish near Bradford Island is expected to be minimal, but native and introduced resident species may forage at the Bonneville Dam Forebay and many of these fish are popular recreational species.

Popular recreational fish species such as largemouth (*Micropterus salmoides*) and smallmouth (*M. dolomieui*) bass are common to the lower Columbia River and could reside in the Bradford Island vicinity. Other introduced fish species such as catfish (*Ameiurus* spp.), yellow perch (*Perca flavescens)*, and walleye (*Stizostedion vitreum*) are also important sport fish that may be present near the landfill for prolonged periods throughout the year.

2.1.4.2.1.2 Wildlife Species

The following wildlife species that are indigenous to this area of the Columbia River Gorge are federally (USFWS, 2014) and/or state (ODFW, 2014) listed as endangered or threatened:

Northern spotted owl (*Strix occidentalis caurina*) – Federally and state-listed threatened

Columbia white-tailed deer (*Odocoileus virginianus leucurus*) – Federally listed endangered

The northern spotted owl lives in old-growth forests of the nearby Mount Hood and Gifford Pinchot National Forests. No old-growth forest exists on Bradford or Cascade Islands, and it is unlikely that adult spotted owls occur there due to lack of suitable nesting habitat. However, juvenile spotted owls might pass through the area.

Columbia white-tailed deer are very unlikely to occur on Bradford or Cascade Islands. Habitat for this species most frequently consists of riparian zones and bottomland hardwood forests and agricultural areas, including islands within the Columbia River downstream of Portland, Oregon (between RM 32 and RM 50), approximately 100 miles downriver from Bonneville Dam.

2.1.5 Historical and Current Land Uses

The Bonneville Project is a multiuse project, managed for hydropower, navigation, recreation, and natural resource and wildlife preservation. The Bonneville Master Plan (USACE, 1997) describes the land use details for the Project. Specific Project uses are described below.

Areas of Bradford Island are specifically managed for wildlife use. Thirteen acres of wooded and open areas on the eastern end of Bradford Island are for multiple resource wildlife management, primarily goose nesting and pasture areas. The open area immediately south of the service building is managed for goose pasture. Geese also use lawn areas associated with the visitor facilities for feeding. The downstream western end of the island has 34 acres used for low density recreational fishing. Eighteen acres on Bradford Island are used for visitor facilities, and the remaining acreage is used for project operations, including office, storage, and equipment maintenance facilities.

There are no plans to change the above land uses at the Project; therefore, these appear to be the likely future land uses. However, consideration is given for potential tribal occupancy of Bradford Island, as this area is within several treaty tribes’ usual and accustomed fishing boundaries. Additional discussion regarding tribal usual and accustomed fishing rights is provided in Section 2.1.5.2.

2.1.5.1 Surrounding Area Land Use

The Bonneville Dam complex lands set aside specifically for project operations include 97 acres of land owned and operated by USACE, and occupied by the main facilities at the Project. The dam complex is located within the Columbia River Gorge National Scenic Area. The Mount Hood National Forest is located south of the dam and south of Interstate 84. Gifford Pinchot National Forest is located on the Washington side of the river, approximately 6.5 miles north of the dam. Beacon Rock State Park is located approximately 2.5 miles to the west, on the Washington side of the river. All of these areas are used for various forms of recreational activities including fishing, boating, hiking, biking, and camping.

The vast majority of land near Bonneville Dam is dedicated to forestry activities, with agriculture a distant second. Timber resources in the region support large, integrated timber processing industries in the major population centers (WDF et al., 1990).

Pierce and Ives Islands are located downstream of the dam at RM 142. Pierce Island is a 200- acre nature conservancy preserve dedicated to protecting native riverine flora and fauna. Ives Island is part of the Gifford Pinchot National Forest and is managed by the Columbia River Gorge National Scenic Area.

Population densities along subbasin tributaries are low, and uses of the streams are not as significant as those along the Columbia River. Habitat alteration and loss due to logging or agriculture are more common threats on these small streams (Washington Department of Fisheries et al. 1990).

2.1.5.2 Population Profiles

The four distinct human populations in the general site area are the site staff, site visitors, nearby residents, and Native American tribes.

Site Staff

The USACE employment at the Bonneville Dam complex is currently approximately 150 full-time-equivalent positions. Staff duties include a wide range of occupations, including maintenance, construction, office staff, visitor services, and natural resource management. Approximately 10 additional staff from the Portland District headquarters are stationed at the dam. Approximately 300 fisheries-related personnel (contractors/researchers from state and federal agencies) work at the dam from April through September. The number of construction and service contractors at the Project varies depending on workloads, but can number approximately 175 people.

Site Visitors

A road from Interstate 84 provides access to the Bonneville Dam complex. The access road is gated, but visitors are allowed to access several dam facilities (visitor centers, fish ladders, etc.). Bradford Island itself is gated and off limits to the public. Only USACE personnel and authorized visitors are allowed into these areas.

Nearby Residents

No permanent residential dwellings are located on the Project. The primary population center in proximity to the dam is the town of North Bonneville, situated on the Columbia River just west of the dam on the Washington side of the river. The current population is estimated at approximately 950 persons.

Major population centers to the west include Portland, Astoria, and St. Helens in Oregon, and Vancouver, Longview-Kelso, and Camas-Washougal in Washington. The cities of Cascade Locks, Hood River, and The Dalles in Oregon and Stevenson, Carson, and White Salmon in Washington lie upstream of the dam. Municipal and industrial pollution from these urban areas is expected to have affected the water quality of the mainstem Columbia River. Population growth is anticipated to result in the conversion of forest, rural residential, and agricultural land uses to high-density residential uses, with potential impacts to habitat conditions (Lower Columbia Fish Recovery Board 2004).

Native Americans

There are four treaty tribes who have treaty rights to engage in fishing from Bradford Island as a usual and accustomed fishing ground. The tribes include the Confederated Tribes and Bands of the Yakama Nation, the Confederated Tribes of the Warm Springs Reservation, the Nez Perce Tribe, and the Confederated Tribes of the Umatilla Indian Reservation. Fishing has strong spiritual and cultural significance for tribes, and fishing along the Columbia River is a historic practice protected by treaty rights. This resource right guaranteed to tribes is the basis for Indian cultural and economic self-sufficiency.

The treaties that the U.S. entered into with several tribes in the 1850s reserves the rights of the tribal members to fish at all usual and accustomed places or sites, and erecting buildings for curing fish. As an example, the Treaty with the Yakama Nation states that "The exclusive right of taking fish in all the streams, where running through or bordering said reservation, is further secured to said confederated tribes and bands of Indians, as also the right of taking fish at all usual and accustomed places, in common with the citizens of the Territory, and of erecting temporary buildings for curing them: together with the privilege of hunting, gathering roots and berries, and pasturing their horses and cattle upon open and unclaimed land." Treaty with the Yakama, June 9, 1855, art. 3 (12 Stat. 951) (emphasis added). The other treaties contain similar language. Members of the treaty tribes have historically fished and erected fishing platforms on the Bradford Island site, and in other locations in the Bonneville forebay. Photographic evidence shows these wooden platforms erected along the steep shoreline of Bradford Island, suitable for possibly holding one or two individuals for fishing purposes (Figure 2-4). Platforms such as those historically seen along the shores of Bradford Island are most common on the larger rivers in the Columbia Basin. These wooden structures are constructed during low-water periods with engineering techniques that have been handed down for generations. Platform sites belong to individual families, and tribal fishers using these scaffolds are likely fishing in the same location their own ancestors did. Successful remedial action may allow tribal fishing to resume on Bradford Island with appropriate risk reduction at the site. Tribes will be permitted to ingress and egress from the island via the pathway adjacent to the site's Visitors Center. Although there are no such current uses, future use is anticipated upon completion of remediation for the Upland and River OUs. For purposes of this Feasibility Study, anticipated future use is quantified for the Upland OU as access for 12 hours per day for an entire lifetime (estimated at 70 years), with exception of the Sandblast AOPC. Because the Sandblast AOPC is primarily used for industrial purposes related to the Bonneville Dam operating project, presence within the Sandblast AOPC is limited to 4 hours per day, representative of tribal subsistence fishers transiting the area to access other portions of the site for fishing.

2.1.5.3 Beneficial Uses

According to ODEQ guidance for determining beneficial water uses (DEQ, 1998), groundwater may be classified as unlikely to be suitable for potable water uses if it meets the criteria of greater than 10,000 milligrams per liter (mg/L) of total dissolved solids (TDS) and yield less than 0.5 gallons per minute (720 gallons per day). Neither the shallow perched groundwater nor the deeper groundwater at Bradford Island appears to meet the yield criterion. A water supply well originally drilled at Bradford Island to supply potable water to on-site workers was left inactive due to inadequate yield. The well was formally abandoned in 2008. Therefore, potable water supply use is a highly unlikely potential beneficial use for groundwater.

Designated beneficial uses for surface water in the mainstem of the Columbia River are described in Oregon Administrative Rules (OAR) 340-41-0101 (DEQ, 2009). They include a variety of high-quality uses such as public and private domestic water supply, fishing, water contact recreation, and protection of fish and aquatic life (Table 2-3). Beneficial use designations for fish uses include salmon and steelhead migration corridors as well as shad and sturgeon spawning and rearing (Table 2-4).

2.2 Investigation History

2.2.1 Historical Investigations and Removal Actions

Multiple investigations have been conducted by USACE and its contractors to evaluate environmental conditions in the Upland OU. As discussed above, the Upland OU includes four AOPCs (Figure 2-3):

- Landfill AOPC
- Sandblast Area AOPC
- Pistol Range AOPC
- Bulb Slope AOPC

Historical investigations of each are discussed below along with supplemental fieldwork and data collection conducted for the Reference Area. Additional detail regarding the results of these investigations can be found in the RI report (URS, 2012).

2.2.1.1 Landfill AOPC

Landfill Site Inspection – August/September 1998

The purpose of the initial (1998) Landfill Site Investigation (SI) was to assess the potential for historical disposal practices to have adversely impacted the environment and to assess whether additional investigation or remediation was necessary (Tetra Tech, 1998). Specific areas of concern that were addressed during the SI included the Landfill, a pesticide/herbicide mixing area located just south of the Landfill, and the shorelines proximate to Bradford Island Landfill.

The SI report concluded that past disposal practices impacted soil and groundwater in the Landfill with petroleum hydrocarbons, organochlorine pesticides, PCB Aroclor 1260, perchloroethylene (PCE), semivolatile organic compounds (SVOCs), arsenic, and lead. Landfill debris encountered in the test pit excavations included mercury vapor lamps, electrical equipment, and asbestos-containing materials. None of the materials encountered in the excavations were removed. Additionally, no groundwater seeps were identified during a visual survey of the sloped banks of Bradford Island in the vicinity of the landfill during September 1998.

Landfill Supplemental Site Inspection – 1999/2000

URS conducted a supplemental site investigation (SSI) of the Landfill for USACE during 1999 and 2000. The purpose of the SSI was to augment information presented in the 1998 SI report, fill data gaps, conduct a risk evaluation, and provide a list of alternatives for the long-term management of the Landfill (URS, 2000).

Results from this investigation and all subsequent investigations at the Landfill AOPC (discussed below) were included in the RI report (URS, 2012). The Draft SSI report (URS, 2000) presented the following conclusions:

Surface and subsurface soils contained relatively low concentrations of volatile organic compounds (VOCs), SVOCs, metals, chlorinated herbicides, organochlorine pesticides, and PCBs.

Groundwater contained relatively low concentrations of VOCs, SVOCs, petroleum hydrocarbons, and metals.

One seep was found and results indicated that low concentrations of metals were detected in the seep water.

The SSI report (URS, 2000) also included a preliminary risk screening for human health and ecological receptors based on landfill contamination. Based on ODEQ's comments on the conclusions presented in the Draft SSI report, USACE elected not to finalize the report. The ODEQ and USACE agreed that additional investigation and analysis were necessary to address ODEQ comments on the SSI report.

Slope Stability Assessment – 2001 and 2015

The discovery of PCB-containing light ballasts along the shoreline during the SSI prompted additional investigations into the nature and extent of the debris, and into the potential for environmental impacts from these materials on ecological receptors in the Columbia River. The light ballasts found along the shoreline were thought at that time to have come from potentially eroded portions of the Landfill. URS conducted a slope stability assessment of the steep shoreline along the landfill in May 2001 to determine whether there was potential for landfill wastes to be transported from the landfill into the Columbia River by slope failures (URS, 2001). There is no evidence that significant and/or multiple rock slope failures have occurred along the north bank slope of the island. Consequently, the possibility that slope failure transported waste from the landfill into the river is low.

In conjunction with the stability assessment, underwater surveys to locate and map the extent of all waste materials in the river were conducted in October and November of 2000, and in May 2001. All wastes identified were removed in December 2000 and March 2002 (URS, 2001) (URS, 2002a) (URS, 2002b) (URS, 2002d).

In 2015 USACE conducted a follow up investigation to reassess slope stability in the area of the landfill. The investigation included a limited review of the geologic literature; review of design documents; review of previous investigation reports related to the landfill and bank slope stability; review of historical aerial photographs and 2010 LiDAR/bathymetry data; and site observations and measurements by USACE civil and geotechnical personnel. Based on site observations and review of historical information, it was concluded that the north bank slope adjacent to the landfill is experiencing erosion as the result of wave erosion. This wave erosion causes the bank to become over-steepened resulting in periodic erosion, soil creep, and shallow landsliding. It was determined that future mass wasting should be anticipated, including shallow landslides that fail to depths of 3 to 10 feet. Future failures will likely mobilize landfill material adjacent to the bank and along the bank, causing fill material (waste material disposed in the landfill) to enter the river. Slope stability analyses completed for this investigation confirmed that the north bank slope is near its natural angle of repose, and has a low Factor of Safety.

Draft Level I Ecological Scoping Risk Assessment and Human Health Problem Formulation – 2002

A Draft Level I Ecological Scoping Risk Assessment and Human Health Problem Formulation report was completed in 2002 for the Bradford Island Landfill (URS 2002 Draft Level). This report discussed (qualitatively) potentially complete exposure pathways and identified contaminants of interest (COIs) for human and ecological receptors. In conclusion, the report recommended that a Level II Ecological Screening Risk Assessment be performed to provide a more thorough evaluation of the potentially complete and significant exposure pathways for ecological receptors based on soil, sediment, groundwater, surface water, and food-web contamination. The report also recommended that a Baseline Human Health Risk Assessment (HHRA) be performed.

Phase II Supplemental Landfill Site Investigation – 2001/2002

The objective of the additional site characterization investigation was to collect site information to assist in the characterization of known or suspected potential environmental concerns at the Landfill (URS, 2004a).

The site characterization report (URS, 2004a) concluded that wastes disposed of within the Landfill include household waste and project-related wastes such as grease, light bulbs, sandblast grit, and miscellaneous metal. Landfill materials and visibly impacted soils did not appear to extend beyond 15 feet in depth. A minimal quantity of electrical debris was observed in the Landfill when compared to the greater amounts removed from within the river or on the shore of the island. There was no evidence that significant and/or multiple past slope failures have occurred along the north bank slope of the island. Consequently, the possibility that slope failures have transported electrical debris to the river was considered low to negligible.

Level II Ecological Screening Risk Assessment and Baseline Human Health Risk Assessment – 2004

A Level II Ecological Screening Risk Assessment and Baseline HHRA report (URS, 2004b) was completed for the Bradford Island Landfill. The Baseline HHRA report concluded (with caveats) that risks to human health at the site were considered acceptable under current land use conditions and that risk reduction measures were not necessary to protect human health. The primary concerns identified in the Level II Ecological Screening Risk Assessment for receptors were the potential for direct exposure toxicity to birds and mammals from contact with Landfill soils. Based on some exceedances of ambient water quality criteria (AWQC) by site groundwater concentrations, additional evaluation of the potential for groundwater to impact surface water quality of the river was recommended.

The Level II Ecological Screening Risk Assessment deferred a quantitative evaluation of risks posed by the aquatic habitat until after sediment remediation. Consequently, an Engineering Evaluation/Cost Analysis (URS, 2005) for in-water sediment removal work was prepared in 2005 and provides an evaluation of human health and ecological risks related to the aquatic environment (primarily from contaminated sediment). Sediment removal was subsequently performed by USACE in 2007 along the north shore of Bradford Island.

Upland Source Evaluation – January to August 2007

In 2007, an Upland Source Evaluation for the Landfill was conducted, which qualitatively evaluated the need for upland source control measures (URS, 2007b) (URS, 2007a). The focus of the evaluation was on direct transport of impacted soil to surface water, either through erosion and transport by storm water or by mass wasting. In April 2007, a limited soil sampling investigation between the Landfill and the river was conducted.

Undercutting was observed along the waterline at the north bank slope suggesting that historical mass wasting likely occurred. The Upland Source Evaluation for the Landfill presented the conclusion that since both slopes are covered with surface vegetation, there appears to currently be a low potential for soil migration via overland transport but that a quantitative erodibility study would be needed to further assess the potential for soil loss.

Supplemental Fieldwork and Data Collection – 2008 to 2012

Fieldwork conducted in the Landfill AOPC after the September 2007 RI/FS Management Plan (MP) was completed (URS, 2008a) included:

- Collection/analysis of groundwater samples from the nine monitoring wells located in the Landfill AOPC during four quarters (March 2008, July 2008, October 2008, and January 2009).
- Survey for groundwater seeps during each quarterly groundwater sampling event.
- Collection/analysis of samples from each observed seep along with the surface water immediately adjacent to the seep.
- Collection/analysis of soil samples from depth intervals of 0-1 foot bgs and 1-3 feet bgs from four test pits.

Upland Erodibility Studies – 2009

Erodibility surveys were carried out in 2009 for each of the three primary AOPCs: the Landfill, Sandblast Area, and Pistol Range AOPCs. Only a visual survey was performed for the Bulb Slope AOPC because this AOPC is a steep, rocky, vegetated slope on the north shore of Bradford Island, which was not suitable for the model used in the erodibility surveys of the other AOPCs.

The objective of these surveys was to estimate the volume of sediment, and associated mass of COIs, potentially transported from each of the AOPCs to the Columbia River. Field surveys of the site were conducted on January 26 and February 5, 2009 (URS, 2009b). The erodibility study identified only a limited portion of the Sandblast Area AOPC, where soils had been temporarily exposed during construction activities, as having a potentially complete pathway associated with stormwater runoff to the river. No currently-erodible soils were identified in the Landfill AOPC or in the Bulb Slope or Pistol Range AOPCs.

2.2.1.2 Sandblast Area AOPC

The "Sandblast Area" is an informal name used during past investigations to describe the former sandblast building and the area around the building where spent blast media (sandblast grit) occurs on the ground surface or where other potential contamination sources may be present (Figure 2-5). Potential contamination sources include:

- Former disposal area for spent sandblast grit
- Former hazardous materials storage area (HMSA) located east of the equipment building
- Former transformer maintenance (disassembly) area east of the former sandblast building
- An inferred release of VOCs (i.e., PCE) from an above-ground storage tank (AST) historically located near the current HMSA
- Laydown area used for current storage of industrial equipment and materials located along the north and south sides of the landfill access road

Stormwater System Sampling and Cleaning–2001 to 2002

Solid materials from the catch basins and near the stormwater system outfalls on the northern perimeter of the Sandblast Area AOPC were sampled in May 2001. Based on the results of the catch basin and stormwater system outfall sampling, the stormwater system was identified as a potential pathway for conveying contaminants from the Sandblast Area AOPC to the river. In October 2001, USACE cleaned the sediment from the stormwater system, replaced the filter fabric socks that line each catch basin, and characterized and disposed of the waste generated during the cleaning process.

Since the stormwater system was identified as a potential pathway for conveying contaminants from the Sandblast Area to the river, USACE developed and implemented a regular inspection and maintenance program to prevent discharge of sediment into the storm drain system (i.e., replacement of the filter socks on a periodic basis). Additional details regarding the stormwater system sampling and cleaning activities can be found in the In Water Investigation Report (URS, 2002a) and the Storm Water Drain Cleaning Summary Technical Memorandum (URS, 2002e). Stormwater system solids were removed and disposed of; therefore, this data was not used in the RI report (URS, 2012).

Preliminary Assessment/Site Inspection Sandblast Area, Transformer Release Area, and Former Drum Storage Area – 2001/2002

A PA/SI of the Sandblast Area was conducted in 2001 to aid in the characterization of environmental concerns associated with the transformer maintenance area, and the former HMSA (also referred to as the former drum storage area) (URS, 2002c).

The burn pit located southeast of the former sandblast building and a septic tank northwest of the building were identified at that time as additional potential sources of contamination within the Sandblast Area AOPC. In addition, evidence of localized solvent-impacted soil was discovered south of the current HMSA.

The PA/SI report estimated that an area of approximately 20,000 square feet and 1 to 3 feet deep (1,500 to 2,000 cubic yards [cy]) might be regulated as hazardous waste if excavated based on lead and chromium concentrations (URS, 2002c). The total volume of sandblast grit present was estimated at between 1,410 and 2,025 cy.

Soil Sampling – 2004

In April and May 2004, USACE cleared the vegetation and graded an area of approximately 1,600 square feet near Catch Basin #1. This work was performed to provide space for the storage of dam gates on several concrete piers. Less than 6 inches of topsoil were excavated by USACE during vegetation removal. The vegetation and some soil connected to the roots were temporarily stockpiled in a roll-off dumpster.

After grading the area, USACE personnel collected surface soil samples from the cleared area as well as soil samples from the dumpster. Based on the results, the soil in the dumpster was disposed of as hazardous waste.

Supplemental Site Inspection – 2004 to 2006

The SSI of the Sandblast Area was conducted in November 2004 to assist in the characterization of known or suspected potential environmental concerns at the Sandblast Area. The investigation method details and analytical results were summarized in the SSI, Sandblast Area (URS, 2006).

The SSI concluded that in addition to metals and butyltins detected during previous investigations, several other COIs were detected in the Sandblast Area AOPC. These included PCBs, SVOCs, and VOCs. The sandblast grit is not believed to be the source of contamination for these COIs. The report (URS 2006) contained the conclusion that the four potential sources of PCB, SVOC, and VOC contamination were:

- Incidental spills of hazardous materials at the southwest corner of the hazardous materials storage area.
- Storage of dam-related equipment along the Landfill access road. Oil-stained soil, metal painted with lead-based paint, and potentially PCB-containing equipment and insulators were observed in this area in 1996.
- Disposal and incineration of wastes in a former burn pit at the east end of the Sandblast Area.
- Transformer maintenance documented in the PA/SI (URS, 2002c). A small release of PCB-contaminated oil occurred in 1995 at the paved area east of the former sandblast building during a transformer rehabilitation project.

Additionally, low levels of petroleum hydrocarbons, VOCs, SVOCs, butyltins, and pesticides were detected in several groundwater samples in the Sandblast Area AOPC. During a previous investigation, air compressor blow-down water was identified as a potential source for lead and bis(2-ethyl hexyl) phthalate (DEHP) identified in river sediments proximate to a drainage outfall north of the former sandblast building (URS 2002 Preliminary Assessment). As part of the SSI, one sample of blow-down water was collected from a pipe that conveys compressor blow-down water from the current sandblasting area in the service center building to the drainage ditch near the former sandblast building. The blow-down water appeared clear, did not have a sheen, and had no unusual odors. Neither DEHP nor lead were detected in the blow-down water sample, but low levels of three SVOCs, four VOCs, and chromium were detected (URS, 2006).

Supplemental Fieldwork and Data Collection – 2008 to 2012

Routine maintenance activities in July 2008 included scraping and stockpiling surface soils to extend the eastern portion of the laydown area. The activity exposed soils that appeared to have tar-like residue (URS, 2009a). USACE elected to perform additional site investigations on the newly exposed soils. The investigations included in the Sandblast Area AOPC included:

- Installation of five groundwater monitoring wells in the Sandblast Area AOPC.

Quarterly collection/analysis of groundwater samples from the five monitoring wells located in the Sandblast Area AOPC.

Collection of surface and near-surface soil samples within known areas of sandblast grit disposal to be sieved into two size fractions and analyzed for lead only.

Collection/analysis of five soil gas samples.

Collection/analysis of five soil samples from five test pits in the newly exposed laydown area.

Collection/analysis of six surface soils from stockpiled soils in the laydown area.

2.2.1.3 Pistol Range AOPC

During the 2002 PA/SI for the Pistol Range, 73 soil samples were collected from 42 sample locations (in some locations samples were collected at different depths). The area investigated was approximately 200 feet long and 20 to 30 feet wide (approximately 4,550 square feet). The investigation method details were summarized in the PA/SI Report for the Former Pistol Range (URS, 2003a). Groundwater data were not collected. In the preliminary screening of the data from the soil samples, the maximum soil concentrations indicated that lead was the only metal elevated above relevant screening criteria at the time (EPA Region 9 Preliminary Remediation Goals [PRGs]), and it was found primarily near the former firing shed and around the backstop (URS, 2003a). These areas appeared to be relatively small (600 square feet around the firing shed, and 1,400 square feet of soil around the backstop) and shallow (impacts likely extend up to 2 feet bgs). The report also included the conclusion that concentrations of both lead and zinc exceeded sediment screening values for the benthic community and could cause a potential concern if the upland soils were transported to the river (URS, 2003a).

Supplemental Fieldwork and Data Collection – 2008 to 2012

Supplemental fieldwork completed between 2008 and 2012 in the Pistol Range AOPC included the collection and analysis of groundwater samples and lagoon sediment samples. Sample locations and analytical results are summarized in Section 6.1.3 of the RI Report (URS, 2012).

2.2.1.4 Bulb Slope AOPC

A reconnaissance investigation of the Bulb Slope area was conducted in November 2002. The investigation and findings are described in the Draft Bulb Slope Reconnaissance Investigation and Evaluation of Potential Remedial Options (URS, 2003b). The investigation included soil samples collected from eight locations.

The investigation report included the conclusion that PCBs as Aroclor 1260, lead, and mercury are present in soils within the area of visually observed glass debris at the Bulb Slope. The report estimated that approximately 95 to 125 cy of debris and impacted soil is present at the Bulb Slope on top of a bedrock base (URS, 2003b).

Slope Stability Assessment – 2017 (in progress)

A visual inspection of the Bulb Slope AOPC in spring of 2017 suggests that possible erosion or mass wasting is occurring from the north face of the Bulb Slope AOPC. As such, USACE is in progress for conducting a geotechnical slope stability assessment. The findings of the assessment and the need for potential mitigation will be addressed in the River OU Feasibility Study.

2.2.1.5 Reference Area

The objective of establishing a Reference Area was to determine site-specific background concentrations of inorganic COIs in soil and groundwater (URS, 2008a). These site-specific background concentrations are interchangeably referred to as reference concentrations throughout this FS. For the Reference Area, the specific location was selected because it was upgradient of an unaffected by the site related waste handling activities. The Reference Area was also found to have samples that generally reflected background or ambient concentrations of all COIs. Lastly, the reference area exhibited similar physical soil characteristics relative to the soil sampled in the four AOPCs in the Upland OU.

The field activities for the Reference Area included:

Installation of the Reference Area groundwater monitoring well (MW-10).

Collection/analysis of groundwater samples from the Reference Area monitoring well during four quarters (March 2008, July 2008, October 2008 and January 2009).

Collection/analysis of fourteen surface soil samples (R1 through R14).

2.2.2 Conclusions from the RI Report

2.2.2.1 Summary of Findings from the RI Report

The RI report, including the screening level Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA), documented current conditions within the Bradford Island Upland OU (URS, 2012). The results are summarized separately for each of the Upland AOPCs below. The HHRA and ERA also evaluated all four AOPCs combined (meaning all four AOPCs were combined to represent a single area) for receptors that could regularly utilize all four AOPCs (i.e., on-site maintenance worker or terrestrial birds and mammals); however, no additional contaminants of potential concern (COPCs) or contaminants of potential ecological concern (CPECs) were identified (when compared to those identified for the individual AOPCs).

Landfill AOPC

2.2.2.1.1.1 Physical and Chemical Characteristics

Historical use of the Landfill AOPC to manage, store, and dispose of waste materials has resulted in contamination of soil, groundwater, and seep water with chemicals associated with the wastes. The extent of the waste disposal area is well defined based on topography, review of historical aerial photographs, a geophysical survey, excavation of test pits, observation of wastes on the ground surface, and the analysis of soil, groundwater, seep, and surface water samples. The type and magnitude of contamination is variable, consistent with the variable waste management, storage, and disposal activities that occurred at the Landfill AOPC.

Soils throughout the Landfill AOPC are impacted by metals, polycyclic aromatic hydrocarbons (PAHs), and other SVOCs. Impacts to soil from butyltins, herbicides, pesticides, PCBs, total petroleum hydrocarbons (TPH), and VOCs are much more limited. Similarly, metals, TPH, and VOCs were detected in groundwater throughout the Landfill AOPC, as well as at low concentrations in seep water sampled along the northern perimeter of the AOPC. Butyltins, herbicides, pesticides, PCBs, PAHs, and SVOCs had generally limited detections in groundwater. Butyltins, herbicides, pesticides, PCBs, and PAHs were not detected in seep water.

The majority of the ground surface at the Landfill AOPC is relatively flat and well vegetated, and shows minimal evidence of surface runoff, soil erosion, or sediment deposition, indicating that the ground surface is stable and there is minimal potential for off-site migration of contaminated soil or buried debris. The north and east sides of the Landfill AOPC include steep slopes leading down to the Columbia River. Although the potential for mass wasting appears low, soil on these slopes has the potential to migrate to the Columbia River via mass wasting.

2.2.2.1.1.2 Human Health Risk Screening

Soils were evaluated for direct contact under occupational and soil-intrusive exposure scenarios, and groundwater was evaluated for hypothetical use as a potable water supply source as well as discharge to the river. COPCs warranting additional consideration in soil at the Landfill AOPC included arsenic, carcinogenic PAHs (cPAHs), and PCE. In addition, the degradation products of PCE as well as chromium and lead were also retained as COPCs according to ODEQ's more conservative screening guidance. In groundwater, the COPCs warranting further consideration included arsenic, manganese, DEHP, Di-n-octylphthalate (DNOP), TPH, and several chlorinated VOCs. Several other VOCs and metals were also identified based on ODEQ's selection process. The vast majority of non-carcinogenic compounds were not a concern. Arsenic and cPAHs emerged as the carcinogenic COPCs contributing most to risk, along with PCE and trichloroethylene (TCE). Arsenic was retained for soil and groundwater at the Landfill AOPC for the Adult Outdoor worker and potable use exposure scenarios; cPAHs were retained for soils for potential direct contact exposures for Adult Outdoor and Construction workers. Areas of the Landfill AOPC that pose the highest potential risk to human health include the Gully Test Pit and the Mercury Vapor Lamp Test Pit (Figure 3-1).

Finally, COPCs in landfill soils identified through the evaluation of potential transport to the River OU via mass wasting or erosion are also recommended for further risk evaluation.

2.2.2.1.1.3 Ecological Risk Screening

Only soil was identified as a medium of concern for ecological receptors at the Landfill AOPC. The following CPECs warrant further consideration for all terrestrial receptors potentially exposed to soil (plants, soil invertebrates, birds, and mammals): antimony, chromium, copper, lead, mercury, nickel, and total high molecular weight PAHs (HPAHs). The areas where the highest concentrations of these CPECs were observed include the mercury vapor-lamp test pit, lead hot-spot test pits #1 and #2, gully test pit, and pesticide/herbicide wash area. In addition, the bioaccumulative CPECs for which dietary-based screening level values (SLVs) are not available also warrant further consideration for birds and mammals (primarily pesticides and herbicides). Finally, CPECs in Landfill soils identified through the evaluation of potential transport to the River OU via mass wasting or erosion are also recommended for further risk evaluation.

Sandblast Area AOPC

2.2.2.1.1.4 Physical and Chemical Characteristics

Historical and ongoing uses of the Sandblast Area AOPC include equipment storage and management, storage, and disposal of various hazardous substances and wastes. These uses have resulted in contamination of soil, groundwater, and soil gas with chemicals associated with the equipment and wastes. The extent of the contaminated area is defined based on topography, location of former and existing site features and structures, knowledge of former and current site uses, visual observation of wastes (i.e. sandblast grit) and equipment on the ground surface, and the analysis of soil, groundwater, and soil gas samples. The sandblast grit disposal area, the equipment laydown area, and an inferred VOC release at the current HMSA appear to be the primary sources of contamination.

Metals, pesticides, PCBs, PAHs, SVOCs, and VOCs were detected in soil samples from throughout the Sandblast Area AOPC. The type and magnitude of contamination is variable, consistent with the variable hazardous substance and waste management, storage, and disposal practices that occurred at the various subareas within the Sandblast Area AOPC. Metals, butyltins, pesticides, PAHs, TPHs, SVOCs, and VOCs were detected at low concentrations in groundwater, indicating that these contaminants are leaching from source area soils to groundwater. PCBs were not detected in groundwater. VOCs were detected in soil gas at locations corresponding to the footprint of the VOC plume originating at the current HMSA. This plume is in an area where there are currently no structures that could be occupied by site workers.

An area of potentially erodible soils, resulting from recent construction activities, was identified during a site visit in 2009. Since 2009 this area has become revegetated and the soils are no longer considered erodible. Stormwater runoff from impervious surfaces (asphalt) drains to four catch basins that discharge to the Columbia River through two outfalls. It appears, however, that the majority of the runoff from asphalt immediately southeast of the former sandblast building flows northeast and discharges onto a short, steep, forested hill slope, where it causes rills to develop on the hill slope. This runoff travels down the slope to the equipment laydown area and adjacent Landfill access road and onto a vegetated area between the Landfill road and the river. Evidence of surface runoff or erosion is absent in this vegetated area, suggesting that runoff flowing onto this area infiltrates the ground before reaching the river.

2.2.2.1.1.5 Human Health Risk Screening

At the Sandblast Area, soils were evaluated for direct contact under occupational and soil-intrusive exposure scenarios and groundwater was evaluated for hypothetical use as a potable water supply as well as discharge to the river. In addition, soil gas was also evaluated for vapor intrusion into future enclosed structures. The COPCs identified in soil were primarily arsenic, chromium, lead, PCE, and cPAHs. In addition, the degradation products of PCE were also identified as COPCs based on ODEQ's selection process. The COPCs in groundwater were arsenic, cPAHs, PCE, TCE and vinyl chloride. Vanadium and some TPH fractions were also identified as COPCs based on ODEQ's selection process. The COPCs in soil gas were primarily PCE, TCE and their degradation compounds. Lead in soil may be a minor contributor to non-cancer hazards at the Sandblast Area AOPC. Arsenic, chlorinated VOCs, and cPAHs were the primary carcinogenic COPCs. VOCs in soil and soil gas are a concern in the vicinity of monitoring wells SB-10 and SB-12.

2.2.2.1.1.6 Ecological Risk Screening

Only soil was identified as a medium of concern for ecological receptors at the Sandblast Area AOPC. The following CPECs warrant further consideration for all terrestrial receptors potentially exposed to soil: antimony, cadmium, chromium, lead, mercury, nickel, DEHP, and total HPAHs. Areas with soil concentrations exceeding ecological screening values occurred throughout the AOPC, including the spent sandblast grit disposal area, around monitoring well CB-1, the equipment laydown area, south of the current HMSA, and within the area where soils were identified as erodible in 2009. In addition, the bioaccumulative CPECs for which dietary-based SLVs are not available also warrant further consideration for birds and mammals (primarily pesticides and herbicides). Finally, CPECs in Sandblast Area soils identified through the evaluation of potential transport to the River OU via erosion are also recommended for further risk evaluation.

Pistol Range AOPC

2.2.2.1.1.7 Physical and Chemical Characteristics

Historical use of the Pistol Range AOPC as a firing range has resulted in the contamination of surface soil with lead and zinc. It is unlikely that significant concentrations of lead or zinc are leaching to groundwater. The Pistol Range AOPC may also be a historical source of zinc to the adjacent lagoon sediment. Currently, the area is well vegetated and does not show evidence of surface runoff, soil erosion, or sediment deposition.

2.2.2.1.1.8 Human Health Risk Screening

At the Pistol Range, soils were evaluated for direct contact under occupational exposure scenarios. Groundwater was evaluated as a hypothetical potable water supply source and for discharge to the river. Lagoon sediments were also evaluated for off-shore exposures. Current and likely exposure pathways for off-site human receptors to COIs from the Pistol Range are insignificant. No COPCs warranting further consideration were identified in soil, groundwater or sediments at this AOPC. The Pistol Range AOPC is not considered to pose a threat to human health under the occupational scenario and was not recommended for any further human health risk evaluation in the RI report (URS, 2012).

2.2.2.1.1.9 Ecological Risk Screening

Only lead in soil was identified as a CPEC and medium of concern for the Pistol Range AOPC. Areas with soil lead concentrations exceeding ecological screening values occurred behind the backstop and at the eastern corner of the former firing shed.

Bulb Slope AOPC

2.2.2.1.1.10 Physical and Chemical Characteristics

Placement of debris at the Bulb Slope AOPC has resulted in the contamination of soil with lead, mercury, and PCBs. The lateral extent of contamination is well constrained by the visible presence of debris in the soil and the underlying siltstone bedrock defines the vertical extent of contamination. Groundwater is not present. Soils may potentially be transported to the adjacent Columbia River by mass wasting.

2.2.2.1.1.11 Human Health Risk Screening

Due to the lack of COPCs for the exposure pathways identified in the conceptual exposure model, the Bulb Slope AOPC is not considered to pose a threat to human health as part of the occupational scenario and was not recommended for any further human health risk evaluation in the RI report (URS, 2012).

2.2.2.1.1.12 Ecological Risk Screening

Lead and mercury in soil were identified as CPECs for the Bulb Slope AOPC. In addition, CPECs in Bulb Slope soils identified through the evaluation of potential transport to the River OU via mass wasting or erosion are also recommended for further risk evaluation.

2.2.2.2 Recommendations from the RI Report

Landfill AOPC

Based on the screening level risk assessments at the Landfill AOPC, implementation of one of two options was recommended in the RI report (URS, 2012):

1. Perform a FS to identify targeted soil removal or other remedial actions which will decrease residual concentrations to acceptable risk levels, or
2. Perform a site-specific Baseline HHRA and a Level III Baseline ERA (ERA) to determine if risks to human and ecological receptors are unacceptable.

Sandblast Area AOPC

Further site-specific evaluation of human exposures to lead in soil using the size fraction-specific data was determined to be unnecessary based on findings in the RI report. However, based on the screening level risk assessment for soil gas at the Sandblast Area AOPC, an evaluation of the feasibility of using a vapor extraction system or other remedial techniques to achieve acceptable soil gas VOC concentrations was recommended in the RI report. In addition, implementation of one of two options was recommended for addressing soil contamination:

1. Perform a FS to identify targeted soil removal or other remedial actions which will decrease residual concentrations to acceptable risk levels, or
2. Perform a site-specific BHHRA and a Level III BERA to determine if risks to human and ecological receptors are unacceptable.

Pistol Range AOPC

No additional evaluation of this AOPC was determined to be warranted for potential human health risk in the RI report (URS 2012). However, further action addressing the potential for risk to ecological receptors from exposure to lead was recommended — either in the form of a Level III BERA or remediation of the soils with elevated CPEC concentrations (primarily behind the backstop). If a Level III BERA is performed for lead in soil to better understand the potential for adverse effects to terrestrial plants, soil invertebrates, birds, and mammals, site-specific factors would be considered (i.e., absence of special-status species, AOPC size [0.26 acres], contribution of background levels of lead, etc.).

Bulb Slope AOPC

No additional evaluation of this AOPC was warranted for potential human health risk in the RI report. However, further action addressing the potential for risk to ecological receptors from exposure to lead and mercury was recommended — either in the form of a Level III BERA or remediation of the soils with elevated CPEC concentrations. If a Level III BERA is performed for lead and mercury in soil to better understand the potential for adverse effects to terrestrial plants, soil invertebrates, birds, and mammals, site-specific factors would be considered (e.g., absence of special-status species, AOPC size [0.05 acres], contribution of background levels of lead and mercury, etc.).

2.3 Data Used in the FS

In this section, data summary tables for the Upland OU presented in Appendix I of the RI report (URS, 2012) are described. No additional data was collected for the Upland OU between the time of finalizing the RI and development of the feasibility study.

A total sample size (including both detections and non-detections) of eight or more is considered necessary for statistical upper-bound estimates of the mean. If the total sample size is less than eight, a upper confidence limit (UCL) cannot be reliably estimated (Singh, Armbya, & Singh, 2010). In the risk assessments, for the cases where sample size was too small (less than eight), the maximum detected concentration was used as the exposure point concentration (EPC) for human receptors and all mobile ecological receptors.

For the population-to-population statistical comparisons to identify COIs at levels that are above reference concentrations (Section 8 of the RI report (URS, 2012)) a minimum number of 14 samples were required to achieve the desired level of confidence in the results. For data sets with fewer than 14 but more than eight samples, population-to-population statistical comparisons were conducted, but the level of confidence associated with the results is lower. For these data sets with even fewer samples, the range in concentrations of the site data was compared to the range of concentrations observed in the Reference Area, and box-and-whisker plots were used to determine whether or not site concentrations were higher than Reference Area concentrations. More information is provided in Section 8 of the RI report.

Tables 2-5, 2-6, 2-7, and 2-8 present the data summaries for the Landfill, Sandblast Area, Pistol Range, and Bulb Slope AOPCs, respectively. The data summary for all four AOPCs combined is presented in Table 2-9, and the Reference Area data summary is presented in Table 2-10. The tables summarize the data by AOPC, medium, analyte group, preparation fraction, analyte, and depth category. The data summary tables provide the number of samples, number of detections, range of detections, and detection rate. All tables also note which data sets are considered limited because they contain fewer than eight samples (a summary of analytes with limited data sets is provided in Table 2-11). They also include the range of minimum detection limits (MDLs) for non-detections, range of minimum reporting limits (MRLs) for non-detections and detections below the MRL (i.e., J-flagged), number of non-detections, number of detections between the MDL and MRL (J-flagged), and number of detections above the MRL.

The following text provides a brief description of the data summaries for the four AOPCs.

2.3.1 Landfill AOPC

Among the soil data sets available for the Landfill AOPC (0 to 1, 0 to 3, and 0 to 10 feet bgs), most have more than eight samples (between 9 and 44 samples) for most of the analytes, with the exception of butyltins, a few herbicides and pesticides, and one SVOC (Table 2-5). With the exception of aluminum, cobalt, and vanadium for the 0 to 1 and 0 to 3 foot depth intervals, the minimum number of 14 samples was achieved for metals and PAHs for population-to-population statistical comparisons. For the butyltins, limited data sets (fewer than eight samples) only occur with soil from 0 to 1 foot bgs; more than eight samples are available for the other two depth intervals. For the herbicides and pesticides and the one SVOC (total benzofluoranthenes), limited data sets are associated with soil from the 0 to 1 and 0 to 3 feet bgs intervals, and more than eight samples are available for the 0 to 10 foot depth interval. It should be noted that more than 14 samples are available for all soil data sets for both benzo(b)fluoranthene and benzofluoranthene, measured as separate analytes.

For the subset of the samples that comprise the data set for mass-wasting soils (samples located within the footprint of the lateral extent for mass-wasting to occur), more than eight samples are available for most metals, pesticides, PCBs, SVOCs, and PAHs, but not for some herbicides, three TPH mixtures, one SVOC (aniline), and some VOCs.

For groundwater, more than 8 samples are available for all analytes (inorganics and organics) measured as total concentrations in this medium. All groundwater samples from the Landfill AOPC were collected from monitoring wells. Data for dissolved-concentrations of analytes are available for the 20 metals analyzed for groundwater, and more than eight dissolved results are available for nine of these metals. Limited data sets are available for seep and surface water data associated with the Landfill AOPC for all analytes.

2.3.2 Sandblast Area AOPC

Among the soil data sets available for the Sandblast Area AOPC (0 to 1, 0 to 3, 0 to 10 feet bgs), more than eight samples (between eight and 81 samples) are available for all analytes, including sieved samples analyzed for lead (Table 2-6). The minimum number of 14 samples was achieved for all metals and PAHs in soil from these three depth intervals, allowing for population-to-population statistical comparison, with the exception of benzo(b)fluoranthene and benzofluoranthene in the 0 to 1 foot bgs data set. Between five and six samples are available for soils collected deeper than 10 feet bgs. In addition, five soil gas samples were collected from the Sandblast Area AOPC.

For the subset of samples that comprise the data set for mass wasting soils (0 to 1 foot bgs), more than eight samples are available for all VOCs, but not for the remaining analytes.

Two types of groundwater data have been collected at the Sandblast Area AOPC: monitoring well samples and direct-push grab samples. For groundwater collected from monitoring wells, more than eight samples are available for arsenic, iron, and vanadium measured as total and dissolved concentrations, and limited data sets are associated with the remaining inorganics (all essential nutrients) that were only measured as dissolved concentrations. More than eight samples are also available for monobutyltin, three TPH mixtures, and the three PAHs analyzed for in groundwater. Fewer than eight samples are available for five of the 65 VOCs analyzed for in groundwater. All monitoring well data for organics were measured as total concentrations. For direct-push groundwater grab samples, more than eight samples are available for all metals, which were measured as both total and dissolved concentrations, and for all VOCs (measured as total concentrations). Fewer than eight samples are available for butyltins, pesticides, PCBs, three TPH mixtures, which were measured as total concentrations. Both total and dissolved concentrations of SVOCs and PAHs were measured in direct-push grab samples, and fewer than eight samples are available for four of the 68 total-concentration samples and 16 of the 67 dissolved-concentration samples (none of these are PAHs).

2.3.3 Pistol Range AOPC

More than eight samples (between 10 and 63 samples) are available for the metals analyzed in soil (0 to 1 foot bgs) from the Pistol Range AOPC (Table 2-7), with lead having the highest number of samples. A limited number data sets are associated with antimony and arsenic. With the exception of antimony, arsenic, molybdenum, and zinc, the minimum number of 14 samples was achieved for metals for the population-to-population statistical comparison.

Fewer than eight samples are available for the four metals (copper, lead, nickel, and zinc) analyzed in lagoon sediment and groundwater direct-push grab samples (measured as both total and dissolved concentrations).

2.3.4 Bulb Slope AOPC

More than eight samples (between 8 and 12 samples) are available for all of the analytes measured in soil (0 to 1 foot bgs) from the Bulb Slope AOPC (Table 2-8): lead, mercury, PCB Aroclors, and TPH. Population-to-population statistical comparisons were performed comparing metals concentrations in the Bulb Slope AOPC to concentrations in the Reference Area; however, the level of confidence in the results was lower than desired.

2.3.5 All Four AOPCs Combined

More than eight samples (between 13 and 199 samples) are available for all of the analytes measured in soil in each of the depth intervals (0 to 1, 0 to 3, and 0 to 10 feet bgs) (Table 2-9). The minimum number of 14 samples was achieved for all metals in soil from all three depth intervals for the population-to-population statistical comparisons.

For groundwater collected from monitoring wells, more than eight samples are available for all analytes (inorganics and organics) measured as total concentrations in this medium. Dissolved-concentration data are available for the 20 metals analyzed in groundwater from the Landfill AOPC, and fewer than eight dissolved results are available for nine of these metals. Limited data sets are available for seep and surface water data associated with the Landfill AOPC for all analytes.

For groundwater direct-push grab samples, fewer than eight samples are available for butyltins, pesticides, PCBs, and three TPH mixtures, which were measured as total concentrations. Fewer than eight samples are available for four of the 68 total-concentration samples and 16 of the 67 dissolved-concentration samples analyzed as SVOCs and PAHs.

2.3.6 Upland Reference Area

Fourteen samples are available for the two classes of analytes measured in Reference Area soils (0 to 1 foot bgs) (Table 2-10), which is sufficient for statistical comparison to site soils. Fewer than eight background groundwater samples are available for all analytes since there is only a single monitoring well located in the Reference Area. Groundwater collected from the Reference Area was not intended for statistical comparisons, but rather a semi-quantitative comparison to groundwater from the three AOPCs with groundwater data.

2.3.7 Feasibility Data Summary

The minimum number of 14 samples is available for most metals and PAHs in soil, which allows for a population-to-population statistical comparison with Reference Area data at the desired level of confidence. In addition, the minimum number of eight samples required to calculate a 95% UCL (i.e., the EPC used for human receptors and all mobile ecological receptors) was achieved for most analytes measured in media of the Upland OU. For those data sets that were intended for statistical comparisons, the EPC for analytes with fewer than eight samples will be based on the maximum concentration because a UCL cannot be estimated reliably (e.g., tributyltin in the 0 to 1 foot interval for Landfill soils). This is consistent with conventional risk assessment guidance (USEPA, 1989). The potential for over prediction or under prediction of risk related to use of the maximum concentration is difficult to assess but does represent the most conservative use of the available data. Some of the data sets identified above as having limited sample size were generally not intended for statistical calculations but rather for assessing nature and extent and for gaining a better understanding of fate and transport mechanisms (e.g., Upland to River migration patterns). This minimizes the uncertainty associated with the small data sets.

2.4 Conceptual Site Model (CSM)

The purpose of the conceptual site model (CSM) is to identify the physical setting and potential sources of contamination, including their transport media and release pathways. The CSM was developed with information gathered from both historical and recent investigations. Because the CSM is "conceptual," it is not dependent on the quantification of the chemical nature and extent and fate and transport.

The physical setting and potential or known sources of contamination in the Upland OU (Figure 2-3) are summarized in this section.

2.4.1 Physical Setting

Physical characteristics of Bradford Island, which are relevant to the discussion of site transport mechanisms, are summarized below.

There are two areas of higher elevation in the center of the island that range from 170 feet to 195 feet above mean sea level (msl). For reference, the Landfill AOPC is at elevation 120, the Sandblast Area AOPC is at elevation 98, and the Pistol Range AOPC is at elevation 94 feet above msl.

River stage elevation upstream of the dam at the island averages approximately 74 feet above msl.

North of the Landfill AOPC, the land surface drops steeply by approximately 30 to 35 feet to the Columbia River. The topography east of the Landfill AOPC also drops steeply to the Columbia River. West of the Landfill AOPC, the topography slopes gently down to the west. Topography in the Sandblast Area AOPC slopes down to the north with areas of varying steepness. The riverbank is armored with rip-rap north of the Sandblast Area AOPC. The Bulb Slope AOPC is situated entirely on the steeply sloping north edge of the island. The land rises moderately south of the Landfill, Sandblast Area, and Bulb Slope AOPCs, and southwest of the Landfill AOPC. The Pistol Range AOPC consists of a pair of vegetated topographic benches stepping down toward the Columbia River to the South. The shoreline is very gently sloped into the adjacent lagoon.

Bedrock outcrops of conglomerate, sandstone, and limited siltstone are exposed along the north bank slope of the island. The potential for bedrock failure is low.

Surface water drainage generally follows sloping topography as sheet flow, before infiltrating into the porous soils, particularly in vegetated areas.

Precipitation that infiltrates the soil at the island may percolate to groundwater. Under both wet season and dry season conditions, shallow groundwater at the island likely flows to the north on the north half of the island and to the south on the south half of the island. Groundwater discharge to surface water occurs as diffuse flow in the high permeability materials in the steep slopes on the northern edge of the island as well as in seeps located in vertical fractures in the underlying low-permeability materials. Groundwater may enter the river through bottom sediments or above-water surface seeps.

2.4.2 Landfill AOPC

The primary sources of COIs released at the Landfill AOPC are trash pits, Landfill mixed-waste disposal areas, and the pesticide mixing area, all related to Department of Defense (DoD) activities. Based on information from previous site investigations including electrical resistivity data, seismic refraction data, and boring logs, the Landfill volume is estimated to be between 7,500 cy and 9,900 cy, with a maximum depth of 15 feet bgs (Tetra Tech, 1998) (URS, 2004a). The waste was buried in separate pits within the Landfill, rather than one large pit. Waste either observed onsite or known to have been disposed of in the landfill includes: household waste, project-related wastes (grease, light bulbs, sandblast grit), electrical debris, up to 50 ballasts, broken glass, rubber tires, metal debris, wood debris, metal cables, asbestos containing building materials, burned debris, ceramic insulators, and mercury vapor lamps. Some exposed wastes have been observed on the northern edge and the surface of the Landfill itself, including concrete rubble, steel cables, a few empty buckets and drums, plastic planter buckets, empty cans and paint solids, and metallic slag and partially-burned construction debris, and miscellaneous trash items. Pesticide/herbicide mixing and rinsing activities historically occurred just south of the Landfill. Stained soils have been observed in the center of the Landfill AOPC (potentially indicating a historical burn area). The Bradford Island Landfill and the equipment storage area in the vicinity of the Landfill AOPC are no longer in use by the Bonneville Dam operation. In 1989, an additional soil cover approximately 8-inches thick was placed on the landfill site by the USACE.

COIs have been released from these primary sources into the soil and groundwater (secondary sources). During wet portions of the year, the groundwater elevation can potentially rise high enough to encounter waste materials in a small portion of the Landfill AOPC. Analytical data demonstrate that soils and/or groundwater are impacted by metals, herbicides, pesticides, PCBs, VOCs, SVOCs (including PAHs), and/or TPH. While there is no visual evidence of current sloughing along the northern perimeter of the Landfill AOPC, undercutting was observed along the waterline at the north bank slope indicating that historical mass wasting likely occurred. Although the potential for bedrock failure is low, if mass wasting were to occur on the steep slopes, the soils may reach the river.

2.4.3 Sandblast Area AOPC

The Sandblast Area AOPC includes the area surrounding the former sandblast building on the eastern end of the site (Figure 2-3). The Sandblast Area AOPC consists of the following subareas that are associated with different sources of contamination:

The formal disposal of sandblast grit in the area immediately east of the sandblast building has resulted in the release of metallic and organometallic constituents, which are used in historical painting operations, into the surface and subsurface of the soil. While a leaching characterization of the sandblast grit itself was not conducted, it can be assumed that the sandblast grit is not having detrimental impacts to the groundwater to such a degree that would result in unacceptable risk to human health or the environment given the pathway to these receptors in the upland is incomplete (as illustrated in further detail in Section 3). Groundwater and seeps are not believed to have unacceptable impacts to the River OU. The presence of sandblast grit has subsequently been transported across the site by surface water runoff into the stormwater drainage features. Given these findings in the RI, elevated contamination at depth is believed to be the result of historic activities. The former HMSA located east of the equipment building, which has potentially resulted in limited soil contamination with metals, pesticides, and PAHs, both at the surface and subsurface.

The paved former transformer maintenance area east of the former sandblast building, at which approximately 1 quart of PCB-containing oil was released on November 22, 1995, and which may have been transported to adjacent soils (secondary source) and possibly the river via the stormwater drainage system.

An inferred release from an above ground storage tank (AST) historically located in the vicinity of the current HMSA, which resulted in the contamination of soil, and subsequently groundwater, with VOCs.

The equipment laydown area used for historical and current storage of industrial equipment and materials located along the north and south sides of the Landfill access road, which appears to have resulted in the contamination of soil with metals, pesticides, PCBs, and SVOCs (including PAHs).

Contaminants have been released from these primary sources (i.e., sandblast grit, PCB-containing oil, hazardous material storage, and equipment storage) to soil and/or groundwater (secondary sources) because of DoD activities. In addition, during a site visit in 2009, an area northeast of the former sandblast building was observed to have been recently disturbed and was identified as erodible, whereby contaminated surface soil could be transported to the river via stormwater drainage and surface water runoff (URS 2009 Upland Operable Unit). Over time, this area has become revegetated and the soils are no longer considered erodible.

2.4.4 Pistol Range AOPC

The Pistol Range AOPC is located approximately 75 feet southeast of the equipment building and north of the Columbia River (Figure 2-3). The pistol range was used for small arms target practice for the DoD from sometime between the early 1940s and the late 1950s to the late 1960s or early 1970s. No other land use associated with the Pistol Range AOPC is known. As a result of the historical land use of the Pistol Range AOPC, the soils immediately adjacent to the firing shed, backstop, and areas down-gradient of the shed and backstop are impacted with selected metals associated with firing range activities.

Currently, the ground surface is vegetated with a mix of scrub-shrub and herbaceous vegetation and does not show evidence of surface runoff, soil erosion, or sediment deposition, indicating that the ground surface is stable. Erosion and transport of soil from the Pistol Range AOPC to the river is currently unlikely. When the Pistol Range AOPC was in use as a firing range the ground surface may have been less vegetated and there may have been historical runoff to the Columbia River (e.g., the adjacent lagoon).

2.4.5 Bulb Slope AOPC

The Bulb Slope AOPC is a fan-shaped accumulation of glass and electrical light bulb debris that extends across approximately 1,900 square feet of a steep slope between the Columbia River and the Landfill access road (Figure 2-3). The Bulb Slope AOPC surface soil is impacted with metals (lead and mercury), PCBs, and TPH from the discarded light bulbs, likely connected to DoD related activities.

The majority of the Bulb Slope AOPC is well vegetated, covered with organic debris, and exhibits no evidence of surface erosion in the vegetated areas. At the base of the slope, however, wave erosion has resulted in mass wasting (small slope failures) of soil with some debris into the river. Mass wasting appears to be the only potential mechanism for transport of debris and/or contaminants in soil into the river.

2.4.6 Nature and Extent of Contamination

2.4.6.1 Landfill AOPC Nature and Extent of Contamination

As previously described, the Landfill AOPC was used by the USACE to manage, store, and dispose of waste materials from approximately 1942 to 1982, with its heaviest use in 1952. The Landfill AOPC encompasses approximately 28,000 square feet on the northeast corner of Bradford Island (Figure 2-6). Based on a review of aerial photographs, the Landfill AOPC was covered by 1982. In 1989, an additional soil cover (approximately 8 inches thick) was placed on the Landfill site by the USACE and the site was managed as a wildlife habitat for geese. Although this portion of Bradford Island is managed as wildlife habitat for geese (USACE, 1997), active management (periodic mowing) of the habitat ceased in the middle to late 1990s to prevent geese from laying eggs in areas that are under investigation. The type and magnitude of contamination in the Landfill AOPC is variable, consistent with the variable waste management, storage, and disposal activities that occurred at the area.

The surface of the actual Landfill AOPC (excluding the steep slopes around the perimeter) slopes gently down to the northwest, north, and northeast, toward the Columbia River. The landfill road runs along the southern margin of the Landfill AOPC. The Landfill AOPC surface is densely vegetated with forest, scrub-shrub, and herbaceous vegetation. The road is more sparsely vegetated with herbaceous vegetation. No evidence of runoff or erosion was observed or predicted through modeling for the Landfill surface (URS 2009 Upland Operable Unit). Minor runoff has been observed on the landfill road. The source of the landfill road runoff is a groundwater seep at the base of the steep slope along the southern margin of the Landfill AOPC. The water flows west along the road and then infiltrates along the northern margin of the landfill road to the west of the Landfill AOPC. The runoff water was clear at the time of the field survey conducted for the RI report (URS 2012), indicating that the flow of seep water along the road is not causing soil erosion. Runoff from the road appeared to infiltrate and evidence of direct discharge of road runoff to the river was not observed (URS, 2009b).

While there is no visual evidence of current sloughing along the northern perimeter of the Landfill AOPC, undercutting was observed along the waterline at the north bank slope indicating that historical mass wasting may have occurred. Although the potential for bedrock failure is low, if mass wasting were to occur on the steep slopes, the soils may reach the river.

Shallow groundwater flows to the north and enters the river through bottom sediments or above water surface seeps.

2.4.6.2 Sandblast Area AOPC Nature and Extent of Contamination

As previously described, contamination at the Sandblast Area AOPC resulted from a variety of historical and ongoing uses that include equipment storage and management, storage, and disposal of various hazardous materials and wastes. The Sandblast Area AOPC has been divided into subareas corresponding to the different uses and associated known or potential sources of contamination: the septic tank drain field area, the spent sandblast media disposal area, two Hazardous Materials Storage Areas (HMSAs), a transformer disassembly area, an equipment laydown area, and a former burn pit (Figure 2-5). The two HMSAs include the former HMSA, also referred to as the drum storage area, and the current HMSA located immediately southeast of the former sandblast building. The former HMSA was investigated because various hazardous and non-hazardous materials were stored there from the early 1980s to the early 1990s and the former HMSA pad did not have secondary contaminant or protective berms. The current HMSA has secondary containment and no documented releases have occurred in this area since its construction. Prior to construction of the current HMSA, a storage tank was reportedly present at this location that is inferred to have been the source of a historical release of VOCs to adjacent soils.

Several site investigations have occurred at the Sandblast Area AOPC since 2001 that focused on individual subareas within the Sandblast Area AOPC and/or the media associated with the individual subareas. Based on the results of these investigations, the three subareas that appear to be the primary sources of contamination are the sandblast grit disposal area, the equipment laydown area, and an inferred VOC release at the current HMSA (Figure 2-5).

There are only three sample locations at the Sandblast Area AOPC (DP11, DP12, and HA12) where samples were collected in deeper soil (3-10 feet bgs). Due to the limited number of samples within the 3-10 feet bgs interval, data from six samples of very deep soil (DP5 through DP10, sampled at > 10 feet bgs) were also included in the evaluation of the deeper soil for nature and extent of contamination at the Sandblast Area AOPC.

The topography of the Sandblast Area AOPC generally consists of a north facing slope with numerous topographic complexities. Upslope of the former sandblast building is a relatively undisturbed and densely vegetated hill slope. Below the upper hill slope is a relatively flat and paved area around the former sandblast building. Downslope (to the north-northeast) of the former sandblast building and the adjacent paved area is a short, steep forested hill slope leading to the flat equipment laydown area and the paved road leading east to the Landfill AOPC. To the northwest of the former sandblast building is a relatively flat, vegetated area, followed by a recently disturbed slope, then a paved road. Recent excavation and filling activities on the slope removed vegetation and exposed bare, erodible soils at the ground surface immediately upslope of catch basin CB-2.

Within the Sandblast Area AOPC, a portion of the stormwater runoff from impervious surfaces (asphalt) drains to four catch basins that discharge to the Columbia River through two outfalls. It appears, however, that the majority of the runoff from asphalt immediately southeast of the former sandblast building flows northeast and discharges onto a short, steep, forested hill slope, where it causes rills to develop on the hill slope. Eroded soil from the rills combined with sandblast grit from further upslope has been observed accumulated at the base of the slope and behind one of two concrete curbs that run along the base of the slope at the equipment laydown area (URS, 2009b).

Evidence of runoff was observed along the landfill access road and the adjacent equipment laydown area. These areas are flat and evidence of erosion is generally lacking. For surface water that does not fully infiltrate, runoff from the road appears to flow north onto a vegetated area between the landfill road and the river. Evidence of surface runoff or erosion is absent in this vegetated area, suggesting that runoff flowing onto this area infiltrates before reaching the river (URS, 2009b). Within the remainder of the Sandblast Area AOPC, particularly in vegetated areas, no evidence of surface runoff, soil erosion, or sediment deposition was observed. In summary, the only complete pathway for direct discharge of surface water from the Sandblast Area AOPC to the river is via the four catch basins.

2.4.6.3 Pistol Range AOPC Nature and Extent of Contamination

As described previously, contamination at the Pistol Range AOPC resulted from historical use of the area as a firing range. Located on the south side of Bradford Island, existing structures at the Pistol Range AOPC include a collapsed wooden firing shed, a secondary firing location, and a timber backstop (Figure 2-7). Based on the location of these structures as well as observation of the area on historical aerial photographs, the Pistol Range AOPC is approximately 200 feet long, 20 to 30 feet wide, and covers an area of approximately 4,550 square feet.

The overall slope of the Pistol Range AOPC is down to the southeast toward the Columbia River. The topography of the area consists of a series of cuts and fills, resulting in a sequence of slopes and flat areas. Currently, the ground surface is vegetated with a mix of scrub-shrub and herbaceous vegetation and does not show evidence of surface runoff, soil erosion, or sediment deposition, indicating that the ground surface is stable. Erosion and transport of soil from the Pistol Range AOPC to the river is currently unlikely. When the Pistol Range AOPC was in use as a firing range, the ground surface may have been less vegetated and there may have been historical runoff to the Columbia River.

Use of the Pistol Range AOPC as a firing range has resulted in the contamination of surface soil with lead and zinc. Nearly all surface soil sample locations have lead and zinc present at concentrations that exceed soil SLVs. It is unlikely that significant concentrations of lead or zinc are leaching to groundwater since the groundwater SLVs are not exceeded. The Pistol Range AOPC may also be a historical source of zinc to the adjacent lagoon sediment. Currently, the area is well vegetated and does not show evidence of surface runoff, soil erosion, or sediment deposition.

Further investigation of the soil northeast of the backstop may be required during remedial design to determine the full extent of contaminated soil in this area.

2.4.6.4 Bulb Slope AOPC Nature and Extent of Contamination

As previously described, contamination at the Bulb Slope AOPC resulted from placement of glass and electrical light bulb debris directly onto a steep slope between the Landfill access road and the Columbia River on the north side of Bradford Island. The debris included various types of light bulbs, glass tubes, clear window pane glass, white molded glass, and miscellaneous glass beverage containers that are variably intermixed with silt, sand, gravel, cobbles, and concrete rubble. The deposit ranges in thickness from about 4 inches near the top of the slope to 5 feet at the base of the slope, and is underlain by siltstone bedrock. Concrete rubble and a small amount of glass debris have been observed in the Columbia River near the riverbank at the base of the Bulb Slope AOPC. The total area of the deposit is about 1,900 square feet (Figure 2-8).

The majority of the Bulb Slope AOPC is well vegetated, covered with organic debris, and exhibits no evidence of stormwater runoff or overland flow to the river. At the base of the slope, however, wave erosion has resulted in mass wasting (small slope failures) of material into the river. Mass wasting appears to be the only potential mechanism for transport of debris and/or contaminated soil into the river.

Twelve surface soil samples were collected from within the area visibly impacted by glass and light bulb debris and analyzed for lead, mercury, and PCBs (as Aroclors). Lead and mercury were detected in all 12 samples. PCBs were detected in eight of the 12 samples. TPH was detected in eight of the 12 samples.

In summary, placement of debris at the Bulb Slope AOPC has resulted in the contamination of soil with lead, mercury, PCBs, and TPH. All surface soil sample locations have one or more contaminants present at concentrations that exceed the applicable soil and/or sediment SLV. The lateral extent of contamination is well constrained by the visible presence of debris in the soil. The underlying siltstone bedrock defines the vertical extent of contamination.

2.4.7 Release Mechanisms and Transport Media

Given the physical characteristics of the site and the current potential sources described above, the following mechanisms were evaluated as potential transport pathways for site contaminants from one or more of the AOPCs to others areas within the Upland OU and/or to the adjacent River OU:

- **Leaching and infiltration of contaminants from contaminated soil to groundwater**. Contaminants found exceeding SLVs or reference area concentrations during the RI consisted primarily of metals, VOCs, and PAHs. Groundwater was subsequently included in the baseline human health risk assessment for the excavation/trench worker receptor. However, groundwater is generally considered an incomplete pathway for any other human or ecological receptors. The Baseline Human Health and Ecological Risk Assessments (Appendix 1) provide a more detailed explanation of exposure pathways and associated risk.

- **Discharge of contaminants in the perched groundwater zone to surface water (via seeps)**. Similar contaminants in the groundwater were correspondingly found in seeps with similar exceedances of SLVs and reference area values. However, despite the presence of these contaminants in seep water, this pathway to surface water between the Upland and River OUs does not present a significant source of recontamination for the potential future remedy in the River OU. During groundwater and seep investigations conducted as part of the RI, metals and VOCs were the primary contaminants that exceeded the SLVs or reference area concentrations. Contaminant concentrations in seep water were generally lower than concentrations observed in groundwater, and fewer analytes exceeded the corresponding Reference Area groundwater concentrations. Arsenic, barium, copper, iron, lead, mercury, selenium, chloroform and PCE were the only analytes for which seep water concentrations exceeded Reference Area concentrations. These contaminants were not detected at corresponding concentrations in the River OU that would cause risk for human health or the environment. Further, PCBs, which are the primary contaminant of concern for the River OU, were either found at concentrations below the SLV or non detect in groundwater and seeps from the Upland OU. Butyltins, herbicides, pesticides, and PAHs were also not detected in seep water. This supports the CSM for the River OU that identifies the primary source of contamination coming from waste deposited directly into the river.

- **Overland transport of spent sandblast grit and surface water runoff of contaminants in soil directly to surface water or via the stormwater drainage system outfalls.** Per the RI, the surface of the landfill itself shows minimal evidence of surface runoff or sediment deposition, indicating that the ground surface is stable and there is minimal potential for migration of contaminated soil by surface erosion to other portions of the upland. For the Sandblast AOPC, "with the exception of the stormwater flow to Catch Basin 1, no other evidence of direct discharge of soil in stormwater to the river has been overserved." Beginning in 2001, USACE cleaned the sediment from the stormwater system associated with this and three other catch basins and replaced the filter fabric socks that line each catch basin. These filter fabric socks are replaced twice annually. As such, there is no suspected contamination transporting from the upland to the river via stormwater and overland transport pathways, but future sampling will need to confirm this. Since the stormwater system solids that were tested in 2001 have been removed and disposed of, this data is not used in assessing contaminant release to the River OU. Additional sampling of the catch basins and outfalls is anticipated during pre-design sampling as well as long term monitoring.

- **Transport of contaminants via soil erosion and/or mass wasting to surface water**. The potential for large scale erosion or mass wasting is most suspected in the vicinity of the northern banks associated with the Landfill and Bulb Slope AOPCs. As such, a geotechnical investigation was conducted for the Landfill AOPC and is currently underway for the Bulb Slope AOPC. The conclusion of the analysis for the area associated with the Landfill AOPC found mass wasting to be occurring and should be addressed to prevent future transport of contaminated soils to the River OU. The results of the analysis for the Bulb Slope AOPC will be document in the River OU Feasibility Study and any potential mitigation will be addressed therein.

2.4.8 Fate and Transport of Contaminants

The fate and transport of contaminants is described below for each of the four Upland OU AOPCs. The sources and nature of releases of contaminants to the environment are summarized, followed by a description of potential or confirmed mechanisms for transport of contaminants from the AOPCs. The understanding of the fate and transport at each AOPC is based on knowledge of historical and ongoing waste management practices and activities, observations of existing site conditions that affect fate and transport, analytical data for soil, soil gas, groundwater, seep water, and surface water, and knowledge of the behavior of chemicals in the environment.

2.4.8.1 Landfill AOPC

The presence of contamination at the Landfill AOPC resulted from use of the area to manage, store, and dispose of waste materials. In addition to the placement of wastes within the Landfill AOPC, other historical activities included pesticide/herbicide mixing and rinsing activities, and use of historical storage areas. Discrete source areas have not been identified within the Landfill AOPC. Rather, the type and magnitude of contamination within the Landfill AOPC is variable, consistent with the variable waste management, storage, and disposal activities that occurred at the Landfill AOPC.

Inorganic and organic contaminants at the Landfill AOPC were initially released to surface and/or subsurface soils. Contaminants that adsorb strongly to soil (e.g., PCBs and PAHs) and are not readily soluble or volatile have likely remained at their point of release. The only potential transport mechanism for insoluble/non-volatile contaminants is to physically move the soil by surface erosion and/or mass wasting of soil. The surface of the landfill itself shows minimal evidence of surface runoff, soil erosion, or sediment deposition, indicating that the ground surface is stable and there is minimal potential for off-site migration of contaminated soil by surface erosion. Around the perimeter of the Landfill AOPC, the potential for mass wasting of soil into the Columbia River appears low. However, metals, pesticides, PCBs, PAHs, and SVOCs were detected in the Landfill AOPC perimeter soil samples at concentrations exceeding the sediment SLVs. There is an ongoing but low potential for these contaminants to be transported off site to the river via mass wasting.

Volatile soil contaminants (e.g., VOCs and SVOCs) can be released to air from surface and subsurface soils. Dust generation can also release volatile and non-volatile soil contaminants in particulate form to air. VOCs and SVOCs were present in surface and subsurface soils at the Landfill AOPC, and therefore there is a potential for volatilization of these chemicals to outdoor air at the Landfill AOPC. However, since the Landfill AOPC is not occupied by site workers, and the ambient conditions are typically windy, the potential for exposure of site workers to volatile constituents in air at levels of concern is extremely low, primarily due to the dispersion of these constituents in air. Since the Landfill surface is well vegetated and vehicles or heavy equipment are not operated on the Landfill surface, the potential for contaminant migration in dust is very low.

Contaminants that may have been initially released as a liquid phase (e.g., PCB-containing oils in buried electrical equipment) can potentially infiltrate into, and migrate through soil as a liquid phase. The extent to which the liquid phase would migrate through soil is in part a function of the release volume and the tendency of the liquid to adsorb to soil. Small releases of liquids that adsorb strongly to soil (e.g., PCB-containing oils) would likely not migrate far from the point of release. Subsurface investigations at the Landfill AOPC have not identified evidence of contaminants present in a liquid phase. In addition, contaminant concentrations measured in soil, groundwater, and seep water at the Landfill AOPC were well below concentrations that would be expected if contaminants were present in a concentrated, liquid phase. Therefore, it is very unlikely that off-site transport of contaminants in soil is an ongoing process at the Landfill AOPC.

A final potential mechanism for off-site transport of contaminants at the Landfill AOPC is leaching of contaminants from buried debris and/or contaminated soil to groundwater, and potential transport to surface water. The degree to which a contaminant may leach to water is mainly a function of its solubility in water, although there are other factors that also affect a contaminants ability to leach. Few contaminants are completely insoluble in water. Leaching of contaminants from surface soil to surface water is a potential transport mechanism at the Landfill AOPC. Surface runoff has been observed originating at the base of the hill south of the Landfill. However, this runoff infiltrates into the ground before reaching the river, and no other evidence of direct discharge of surface water to the river has been observed at the Landfill AOPC.

Groundwater analytical data confirm that most contaminants detected in surface and subsurface soils were also detected in groundwater. The mechanism for this leaching is likely a combination of leaching directly to infiltrating precipitation in unsaturated soil as well as to groundwater where Landfill wastes are saturated by the seasonal high water table. Seep water analytical data indicate that metals, DRO, and selected VOCs at concentrations exceeding the surface water SLVs have migrated in groundwater to seeps. However, seep water is rapidly diluted upon discharge to the river, as demonstrated by the fact that DRO and VOCs were not detected in concurrent samples of adjacent surface water. SVOCs also appear to have migrated to the seeps but at concentrations below the surface water SLVs. Butyltins, herbicides, pesticides, and PAHs were detected in groundwater but not seep water, indicating that they may be leaching to groundwater but are not migrating to the river. PCBs were not detected in groundwater or seep water, consistent with the very low solubility of PCBs in water.

In summary, the primary mechanism for off-site transport of contaminants from the Landfill AOPC appears to be leaching of contaminants from buried debris and/or contaminated soil to groundwater, and discharge of contaminants in the groundwater zone to the river via seeps. The COPCs potentially transported through this migration pathway are metals, TPHs, and VOCs. There is also a low potential for metals, pesticides, PCBs, PAHs, and SVOCs in soil to migrate to the river via mass wasting of soil.

2.4.8.2 Sandblast Area AOPC

Contamination at the Sandblast Area AOPC resulted from a variety of historical and ongoing uses that include equipment storage and management, as well as storage and disposal of various hazardous materials and wastes. The type and magnitude of contamination is variable, consistent with the variable hazardous substance and waste management, storage, and disposal practices that occurred at the various subareas within the Sandblast Area AOPC. Some contaminants are widespread in soil and groundwater and are not associated with a discrete source within the Sandblast Area AOPC. Other contaminants appear to be specifically associated with the sandblast grit disposal area, the equipment laydown area, and an inferred VOC release from a storage tank previously located where the HMSA is currently located.

Inorganic and organic contaminants at the Sandblast Area AOPC were initially released to surface and/or subsurface soils. Throughout much of the Sandblast Area AOPC, contaminants that adsorb strongly to soil and are not readily soluble or volatile have likely remained at their point of release. However, observation of the site conditions confirm that soil erosion is a historical and ongoing process that has mobilized and transported soil within portions of the Sandblast Area AOPC. Soil erosion is the result of stormwater runoff from impervious surfaces, as well as direct precipitation onto and runoff from soils recently disturbed by excavation and filling activities. Stormwater from the northwest portion of the Sandblast Area AOPC drains to four catch basins; two stormwater pipe outfalls convey runoff from the catch basins to the Columbia River. The catch basin drainage areas include areas where soil erosion and transport is documented. Metals, PCBs, TPH, butyltins, pesticides, SVOCs, PAHs, and VOCs were detected in erodible soil, and constituents of each of these analytical groups, except TPH and VOCs, had concentrations that exceeded sediment SLVs. Metals, butyltins, PCBs, and TPHs were detected in soil along the stormwater flow path to CB-1, and/or in soil immediately adjacent to CB-1. With the exception of the stormwater flow to CB-1, no other evidence of direct discharge of soil in stormwater to the river has been observed at the Sandblast Area AOPC.

Soil gas analytical data from soil borings confirm that VOCs were present in soil gas at, and down-gradient of, the inferred PCE source area at the current HMSA. VOC concentrations exceeded soil gas SLVs but not at locations occupied by site workers. Thus, VOCs are potentially being released to air. Volatile and non-volatile contaminants were present in surface soils at locations that are barren and/or experience infrequent vehicle traffic. There is a potential for transport of volatile and nonvolatile soil contaminants in dust, but this transport mechanism is likely very minor. To the extent that soil adheres to vehicle tires in the Sandblast Area AOPC, there is also a potential for transport of contaminants along road ways within the Sandblast Area AOPC and elsewhere at Bonneville Dam, although this mechanism is likely minor due to the minimal vehicle traffic at the Sandblast Area AOPC.

A storage tank was reportedly present at the location of the current HMSA prior to its construction. VOC concentrations in soil, soil gas, and groundwater indicate that a PCE release occurred at this location, and the former storage tank is the inferred source of the release. Very high concentrations of PCE and TCE were reported in soil adjacent to the current HMSA; elsewhere, VOC concentrations were much lower. Evidence of liquid phase contamination was not observed in soil borings or monitoring wells down-gradient of the current HMSA. Groundwater analytical data demonstrate that VOC concentrations at the inferred source area are decreasing over time. The analytical data and soil boring/monitoring well observations suggest that liquid phase contamination may have been present in soil at or in the vicinity of the former storage tank at the time of the release. But it appears unlikely that significant migration of liquid phase contamination occurred. Evidence of liquid phase contamination has not been encountered elsewhere at the Sandblast Area AOPC.

Leaching of contaminants from surface soil to surface water is a potential transport mechanism at the Sandblast Area AOPC. As described above, metals, PCBs, TPH, butyltins, pesticides, SVOCs, PAHs, and VOCs have been detected in soil within the drainage area of the four stormwater catch basins. Since many of these contaminants are soluble in water, off-site transport of dissolved-phase contaminants in stormwater may be occurring at the Sandblast Area AOPC. Groundwater analytical data confirm that most contaminants detected in surface and subsurface soils have leached to groundwater. Metals, butyltins, pesticides, PAHs, TPHs, SVOCs, and VOCs were detected in groundwater. PCBs were not detected in groundwater, consistent with the very low solubility of PCBs in water. Concentrations of metals, PAHs, and VOCs in groundwater exceeded their surface water SLVs, including at locations immediately adjacent to the river, indicating that these contaminants may be migrating to the river at concentrations of potential concern. Butyltin, pesticide, TPH, and SVOC concentrations did not exceed SLVs. Seeps have not been observed along the river bank at the Sandblast Area AOPC, but groundwater is assumed to discharge to the river as base flow.

In summary, the primary mechanisms for off-site transport of contaminants from the Sandblast Area AOPC appear to be soil erosion and transport in stormwater to the river, and leaching of contaminants from contaminated soil to groundwater followed by discharge of groundwater to the river via base flow. The potential contaminants of concern to one or both of these transport mechanisms include metals, butyltins, pesticides, PCBs, PAHs, TPH, SVOCs, and VOCs. There is also a potential for off-site migration of soluble contaminants in stormwater, as confirmed by stormwater sampling in 2001 and 2002. However, engineering controls have since been implemented that minimize the likelihood of this potential pathway.

2.4.8.3 Pistol Range AOPC

Use of the Pistol Range AOPC as a firing range resulted in the contamination of soil with lead and zinc. The highest lead concentrations in soil are at and behind the backstop, and are likely associated with bullet fragments that remain in the soil. In lagoon sediment adjacent to the Pistol Range AOPC, zinc concentrations exceeded the sediment SLV and were also higher than the maximum concentration of zinc detected elsewhere in Forebay sediments. The analytical data indicate that historically, when the firing range was in use, off-site migration of metals to the river may have occurred as a result of soil erosion and/or soluble transport in stormwater. Currently, however, the Pistol Range AOPC is well vegetated and does not show evidence of surface runoff, soil erosion, or sediment deposition. Similarly, since the Pistol Range AOPC is well vegetated and vehicles or heavy equipment are not operated at the site, the potential for migration of metals in dust is very low.

Total concentrations of copper, lead, nickel, and zinc, and dissolved concentrations of copper, nickel, and zinc were detected in groundwater at the Pistol Range AOPC, although no detected concentrations exceeded the water SLVs. Although the soil conditions beneath the Pistol Range AOPC accommodate very little groundwater (most of the holes drilled were dry), the analytical data from the two groundwater samples collected suggest that metals have leached to groundwater to a limited extent. The discharge of this groundwater to the river as base flow may provide a mechanism for transport of metals to the river, but not at concentrations of potential concern.

In summary, minor leaching to groundwater followed by discharge of groundwater to the river via base flow is the only (very limited) mechanism of transport of contaminants from the Pistol Range AOPC to the river.

2.4.8.4 Bulb Slope AOPC

Contamination at the Bulb Slope AOPC resulted from placement of glass and electrical light bulb debris directly onto a steep slope between the landfill access road and the Columbia River. Lead, mercury, PCBs, and TPH have been detected in surface soils at the Bulb Slope AOPC. The majority of the Bulb Slope AOPC is well vegetated, covered with organic debris, and exhibits no evidence of surface erosion from the vegetated areas to the river. Wave erosion at the base of the slope has resulted in mass wasting of soil which appears to be a potential mechanism for transport of debris and/or contaminants in soil into the river. Owing to the well vegetated nature of the Bulb Slope AOPC, the potential for migration of contaminants in dust is very low.

There is a low potential for metals and TPHs to leach from the soil into groundwater and discharge to the river as base flow. Given the thin soil layer and small footprint of the Bulb Slope AOPC, and the fact that it is well-vegetated with trees and shrubs, leaching to groundwater is unlikely to be a significant transport mechanism. PCBs have a very low solubility in water and are unlikely to leach to groundwater or surface water.

2.5 References

Beeson, M. H., & Tolan, T. L. (1987). Columbia River Gorge: The Geologic Evoluation of the Columbia River in Northwestern Oregon and Southwestern Washington. *Cordilleran Section of the Geological Society of America.*

Center, O. B. (2014, December 10). *Rare, threatened, and endangered species of Oregon: species ranking*. Retrieved from http://orbic.pdx.edu/rare-info.html

DEQ. (1998, July). Guidance for Conducting Beneficial Water Use Determinations at Environmental Cleanup Sites. Retrieved March 23, 2006, from http://www.deq.state.or.us/wmc/documents/wateruse.pdf

DEQ. (2009, November). Oregon Administrative Rule (OAR) 340-041. Chapter 340, Division 41: Water Quality Standards: Beneficial Uses, Policies, and Criteria for Oregon. Tables 33A, 33B, and 33C.

Hibbs, D. (2001). USACE. Personal Communication.

Holdredge, C. P. (1937). Final Geological Report on the Bonneville Project. *U.S. Army Corps of Engineers, Portland District, Oregon*.

Leland, D. (2001). Manager, Oregon Department of Health Services. (B. M. URS, Interviewer)

Lower Columbia Fish Recovery Board. (2004, December 15). Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan.

McCavitt, B. (2001). Environemental Site Manager, USACE. (B. M. URS, Interviewer)

McCavitt, B. (2006). Environmental Site Manager, USACE. (U. Chris Moody, Interviewer)

National Marine Fisheries Service. (2000). Letter dated January 10, 2000, to Jeff Wallace, URS Greiner Woodward Clyde.

NPCC. (2004). *Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan.*

ODFW. (2014, December 10). *Threatened, endangered, and candidate fish and wildlife species in Oregon*. Retrieved from http://www.dfw.state.or.us/wildlife/diversity/species/threatened_endangered_candidate_list.asp

Oregon Natural Heritage Information Program. (2007). Rare, Threatened, and Endangered Species of Oregon: Species Ranking. *Oregon Natural Heritage Information Center*. Retrieved December 7, 2009, from http://oregonstate.edu/ornhic/ranking.html

Oregon Natural Heritage Program. (1999). Leter and attachments dated August 3, 1999, to URS Greiner Woodward Cycle.

Orr, E. L., & Orr, W. N. (1999). Geology of Oregon. *Iowa: Kendall/Hunt, Fifth.*

Perletti, K. (2010, February 8). Mechanical Engineer, USACE. (U. Mike Ross, Interviewer)

Sager, J. (1989). Bonneville Dam. In Engineering Geology in Washington. *Washington Division of Geology and Earth Resources Bulletin 78*.

Scofield, D. (1998). Bonneville Fish Hatchery Well Field, Columbia River Gorge, A Case Study of River-Groundwater Interaction. In Burns, S., ed., Environmental Groundwater and Engineering Geology,. 567-578.

Singh, A., Armbya, N., & Singh, A. K. (2010). ProUCL Version 4.1.00 Technical Guide Draft, Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. EPA/600/R-07/041.

Tetra Tech. (1998, December). Final Site Investigation Report, Bradford Island Landfill, Cascade Locks, Oregon. Prepared for U.S. Army Corps of Engineers, Portland District. Contract No. DACW57-96-D-0009. Task Order No. 0010.

Troffe, P. (1999). Freshwater Fishes of the Columbia Basin in British Columbia. Living Landscapes, Royal British Columbia Museum. Retrieved from http://livinglandscapes.bc.ca/peter_nyles/pdf/fish1e.pdf

United States Fish and Wildlife Services (USFWS). (1999). Letter dated October 12, 1999, to URS Greiner Woodward Clyde.

URS. (2000). Draft Supplemental Site Inspection, Bradford Island Landfill. *Cascade Locks, Oregon*.

URS. (2001, May). Draft Geotechnical Design Report, North Slope Regrade and Stabilization, Bradford Island Landfill. Cascade Locsk, Oregon.

URS. (2002a). In Water Investigation Report, Bradford Island Landfill.

URS. (2002b). In Water Removal Work, Bradford Island Landfill, Cascade Locks, Oregon. Technical Memorandum.

URS. (2002c). Preliminary Assessment/Site Inspection. Sandblast Area, Transformer Release Area, and Former Drum Storage Area. Bonneville Lock and Dam Project, Cascade Locks, Oregon.

URS. (2002d). Draft Level I Ecological Scoping Assessment and Human Health Problem Formulation, Bradford Island Landfill. Bonneville Lock and Dam, Cascade Locks, Oregon.

URS. (2002e). Storm Water Drain Cleaning Summary. Technical Memorandum.

URS. (2003a). Draft Preliminary Assessment and Site Inspection, Former Pistol Range. Bonneville Lock and Dam Project, Cascade Locks, Oregon.

URS. (2003b). Draft Bulb Slope Reconnaissance Investigation and Evaluation of Potential Remedial Options. Bradford Island. Bonneville Lock and Dam Project, Cascade Locks, Oregon.

URS. (2004a). Site Characterization Report, Bradford Island Landfill, Bonneville Lock and Dam Project, Cascade Locks, Oregon. Prepared for the USACE (Portland District).

URS. (2004b, May). Level II Screening Ecological Risk Assessment and Baseline Human Health Risk Assessment, Bradford Island Landfil. Revised Draft Reportl. Bonneville Dam, Cascade Locks, Oregon.

URS. (2005). Draft Engineering Evaluation and Cost Analysis, Bradford Island Disposal Site, Bonneville Dam Forebay, Cascade Locks, Oregon.

URS. (2006). Supplemental Site Investigation, Sandblast Area, Bonneville Lock and Dam Project, Cascade Locks, Oregon.

URS. (2007a). Technical Memorandum - Upland Source Evaluation - Bradford Island Landfill, Bulb Slope, and Site 7, Bradford Island and Bonneville Dam Forebay, Cascade Locks, Oregon and Bonneville Lock and Dam Forebay, Cascade Locks, Oregon.

URS. (2007b). Technical Memorandum - Upland Source Evaluation - Bradford Island Landfill, Bradford Island and Bonneville Lock and Dam Forebay, Cascade Locks, Oregon.

URS. (2008a). QAPP, Upland Operable Unit Remedial Investigation, Bradfor Island, Bonneville Lock and Dam Project, Cascade Locks, Oregon.

URS. (2008b). Technical Memorandum: Post-Removal Sample Collection, Bradford Island Disposal Site, Bonneville Dam Forebay, Cascade Locks, Oregon.

URS. (2009a). Upland QAPP Addendum, Bradford Island Upland Operable Unit Remedial Investigation, Cascade Locks, Oregon.

URS. (2009b). Upland Operable Unit Data Gap Sampling January-March 2009, Bradford Island Remedial Investigation, Cascade Locks, Oregon.

URS. (2012). *Remedial Investigation Report: upland and river operable units. Bradford Island, Cascade Locks, Oregon.*

USACE. (1991, September 6). Bonneville Navigation Lock Sediment Evaluation. . *CENPP-PE-HR, Jim Britton*.

USACE. (1997). Columbia River Basin Oregon - Washington Bonneville Locak and Dam, Bonneville Master Plan, Final March 1997.

USACE. (1998). *Navigation Conditions at Bonneville Locks and Dam, Columbia River.* Ronald T. Wooley.

USACE. (2001). Environmental Review Guide for Operations, External Compliance Audit, Bonneville Lock and Dam.

USACE. (2005). *Seattle District, Water Resources Division, Mid-Columbia River Basin.* Retrieved December 27, 2005, from http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=waterres&pagename=midcolumbia

USACE. (2007, January). Biological Assessment for Anadromous Fish Species and Steller Sea Lion Essential Fish Habitat, Removal of Contaminated Sediment Bradford Island, Columbia River Multnomah County, OR.

USEPA. (1989, December). Superfund Risk Assessment Guidance for Superfund, Volume I Human Health Evaluation Manual (Part A), Interim Final. EPA/540/1-89/002.

USFWS. (2009). Threatened, Endangered, and Candidate Fish and Wildlife Species in Oregon. Oregon Fish and Wildlife Office. Retrieved December 6, 2009, from http://www.dfw.state.or.us/wildlife/diversity/species/threatened_endangered_candidate_list.asp

USFWS. (2014, December 10). *Threatened/endangered wildlife in the US: listed animals.* . Retrieved from http://ecos.fws.gov/tess_public/pub/listedAnimals.jsp

USGS. (1996). *Water Quality of the Lower Columbia River Basin: Analysis of Current and Historical Water-Quality Data through 1994. Water Resource Investigation Report 95-4294.*

WDF et al. (1990). Washington Department of Fisheris, Lead, Washington Department of Wildlife and Oregon Department of Fish and Wildlife, Co-Authors. Lower Columbia River Subbasin, Salmon and Steelhead Production Plan.

Western Regional Climate Center. (2002). Desert Research Institute. *Historical Climate Information Database*. Retrieved December 29, 2005, from http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?orbonn

Wise, W. S. (1970). Cenozoic Volcanism in the Cascade Mountains of Southern Washington. *Washington Division of Mines and Geology Bulletin 60*. Olympia.

3 Risk Assessment Summary

Baseline ecological and human health risk assessments were completed for the Bradford Island Upland OU in 2016. This section summarizes the findings of both risk assessments, which are used in Section 4 of this feasibility study to aid in establishing remedial action objectives (RAOs) and preliminary remediation goals (PRGs). Additional details on the methods and results can be found in the Risk Assessments contained in Appendix 1.

These baseline risk assessments were conducted after completion of the Remedial Investigation (RI) as a component of this Feasibility Study (FS). The Final RI Report (URS, Remedial Investigation Report: upland and river operable units. Bradford Island, Cascade Locks, Oregon, 2012), identified contaminants of potential concern (COPCs) for human health and contaminants of potential ecological concern (CPECs) during screening level risk assessments and recommended site-specific baseline ecological risk assessments (ERAs) and baseline human health risk assessments (HHRAs) for the Landfill and Sandblast Area AOPCs and site-specific baseline ERAs for the Pistol Range and Bulb Slope AOPCs. In consultation with the Technical Advisory Group an assemblage of technical resources and stakeholders to provide review and technical input during the cleanup process, USACE elected to include a Fishing Platform scenario, in addition to the occupational receptors, for human health at all four AOPCs as part of the baseline HHRA.

The baseline ERA is discussed in Section 3.1, and presents the estimated risk for terrestrial plants, soil invertebrates, and wildlife receptors exposed to contaminants primarily through direct contact or incidental ingestion of soil, prey, and water that collects in the Upland OU.

The baseline HHRA is discussed in Section 3.2, and presents the estimated risk for people who may be exposed to contaminants on the Bradford Island Upland OU through direct contact or incidental ingestion or inhalation of soil, groundwater, and soil vapor.

After finalization of the baseline risk assessments, stakeholder input was incorporated to account for additional exposure scenarios for the fishing platform scenario. USACE calculated risk for additional scenarios that assumed 4 hour and 12 hour daily exposure durations in the Sandblast and Landfill AOPCs, respectively. A 70 year averaging time was also applied for each of these scenarios based on stakeholder input. The purpose of these additional exposure scenarios are intended to represent tribal fishing platform receptors transiting across the Sandblast AOPC (4 hours) and fishing during daylight hours in the Landfill AOPC. Given that tribal fishing receptors can be expected to reside and fish from a single location for their lifetime, the averaging time was increased to 70 years to reflect this. The results of this supplemental analysis are incorporated into this section and provided as an addendum to Appendix 1.

The risk-based threshold concentrations (RBTCs), discussed in Section 3.3, represent calculated soil concentrations estimated to be protective of a particular receptor for a given exposure pathway and target risk level. The RBTCs were derived based on the baseline ERA and HHRA, and along with other site information, are used to establish PRGs in Section 4. Finally, this section concludes with a summary of key findings from the risk assessments (Section 3.4) and cumulative risk considerations for the Upland OU (Section 3.5).

3.1 Baseline Ecological Risk Assessment

The Baseline ERA (Appendix 1), equivalent to Oregon DEQ's Level III Ecological Baseline Risk Assessment, estimated risks for ecological receptors that may be exposed to contaminants in soil and surface water collecting on the island, and through consumption of prey on Bradford Island.

Seven receptors of concern were selected in the baseline ERA to represent groups of organisms inhabiting Bradford Island with the same exposure pathways. These receptors of concern include terrestrial plants, the soil invertebrate community (soil invertebrates), Canadian goose (goose), American robin (robin), American kestrel (kestrel), vagrant shrew (shrew), and American mink (mink).

The results of the baseline ERA summarized below are based on both:

- low screening levels (SLVs)/no observable adverse effect level (NOAEL) toxicity reference values (TRVs) and
- high SLVs/lowest observable adverse effect levels (LOAEL) TRVs.

Both low SLVs/ NOAEL TRVs and high SLVs/LOAEL TRVs were selected for each receptor group in order to develop a range of Hazard Quotients (HQs) for consideration when identifying contaminants of ecological concern (CECs) and risk drivers. SLV values are used to estimate risk for terrestrial plants and soil invertebrates whereas TRV values are relevant for birds and mammals. For purposes of this feasibility study, CECs are defined as CEPCs with HQs greater than or equal to 1.0 primarily based on LOAEL TRVs and high SLVs. Table 3-1 summarizes the identified CECs along with both the low SLVs/ NOAEL TRVs and high SLVs/LOAEL TRVs for each receptor of concern.

All four Areas of Potential Concern (AOPCs) in the Upland OU were evaluated in the baseline ERA. Surface soil (0-1 ft bgs) and shallow soil (0-3 ft bgs) were identified as media of concern for ecological receptors based on decisions made during the Remedial Investigation. The ecologically relevant soil depth interval is expected to be limited primarily to chemicals in the upper 3 feet at the Upland AOPCs. Surface soils will be defined as 0 to 1 foot bgs, and subsurface soils defined as 0 to 3 feet bgs. Rooting depths for plants and burrowing depths for invertebrates and mammals will be assumed to occur within the upper 3 feet of soil, and it will be assumed that all terrestrial receptors are exposed to soils from this depth interval. Although not all birds and mammals burrow, these receptors typically consume organisms that are exposed to soils below the surface. The following contaminants of potential ecological concern (CPECs) were carried into the baseline ERA for the identified AOPCs:

- Landfill and Sandblast Area AOPCs: metals, total high-molecular-weight PAHs (Total HPAHs), tributyltin, organochlorine pesticides, volatile organic compounds (VOCs), and semi-volitile organic compounds (SVOCs)
- Pistol Range AOPC: lead
- Bulb Slope AOPC: lead and mercury

All of these CPECs were included in the baseline ERA, and wide-ranging receptors were assumed to forage in all four Upland AOPCs combined. Risk estimates were calculated for each CPEC for all receptors potentially present at a given AOPC. These risk estimates calculated for each CPEC were used to identify CECs.

3.1.1 Landfill AOPC

From the CPECs identified, a subset of CECs were selected for additional evaluation at the Landfill AOPC due to the potential for adverse effects to populations of invertivorous (feeding on invertebrates) birds or mammals, or community-level impacts to plants and invertebrates. Those CECs include the following seven contaminants: chromium, copper, lead, mercury, nickel, chlordane (technical mixture and metabolites; hereafter simply referred to as "chlordane"), and Total HPAHs. The following paragraphs identify which CECs were selected for which receptors and media at the Landfill AOPC.

For terrestrial plants in surface soil, chromium, mercury, chlordane, and Total HPAHs have Hazard Quotients (HQs) greater than 1.0 based on the low SLVs and high SLVs; copper, lead, and nickel have HQs greater than 1.0 based on only the low SLVs, thus screening them out as CECs. For terrestrial plants in shallow soil the same seven CPECs (as those just listed for surface soil) have low SLV-based HQs greater than 1.0; chromium, nickel, chlordane, and Total HPAHs have high SLV-based HQs greater than 1.0.

Soil invertebrates in surface soil have HQs greater than 1.0 based on the low SLVs and high SLVs for chromium, mercury, and Total HPAHs. In addition to these CPECs, copper also has an HQ greater than 1.0 based on the low SLV. For soil invertebrates in shallow soil, chromium, mercury, Total HPAHs, copper, and nickel have low SLV-based HQs greater than 1.0. For soil invertebrates in shallow soil chromium, mercury, and Total HPAHs also have high SLV-based HQs greater than 1.0.

The robin has HQs greater than 1.0 based on the NOAELs and LOAELs for chromium, copper, lead, mercury, nickel, and chlordane in surface and shallow soil. In addition to these CPECs, bis(2-ethylhexyl) phthalate (DEHP) also has an HQ greater than 1.0 for the robin based on the NOAEL in both surface and shallow soil. Given the minor exceedances of the HQ threshold and uncertainty associated with the NOAEL, DEHP was not carried forward as a CEC.

The shrew has HQs greater than 1.0 based on the NOAELs and LOAELs for chromium, copper, lead, mercury, nickel, chlordane, and Total HPAHs in surface soil. In addition to these CPECs, antimony also has an HQ greater than 1.0 for the shrew for surface soil based on the NOAEL. For the six CPECs listed above for surface soil for the shrew, they also have HQs greater than 1.0 for shallow soil for the shrew.

3.1.2 Sandblast Area AOPC

From the CPECs identified, a subset of CECs were selected in the baseline ERA at the Sandblast Area AOPC due to the potential for adverse effects to populations of invertivorous birds or mammals represented by the robin and shrew, or community-level impacts to plants and invertebrates. These CECs include the following: antimony, chromium, lead, nickel, DEHP, and Total HPAHs. The following paragraphs identify which CECs were selected for which receptors and media at the Sandblast Area AOPC.

For terrestrial plants in surface soil, chromium, nickel, and Total HPAHs have HQs greater than 1.0 based on the low SLVs and high SLVs. In addition to these CPECs, lead, and gamma-benzene hexachloride (BHC; lindane) also have HQs greater than 1.0 based on only the low SLVs. For terrestrial plants in shallow soil, chromium, nickel, Total HPAHs, lead, and lindane also have low SLV-based HQs greater than 1.0, with the exception of gamma-BHC for which the HQ is less than 1.0. Chromium, nickel, and Total HPAHs have high SLV-based HQs greater than 1.0 for terrestrial plants in shallow soil.

For soil invertebrates in surface soil, chromium has HQs greater than 1.0 based on the low SLVs and high SLVs. In addition to chromium, mercury, nickel, and Total HPAHs also have HQs greater than 1.0 based on the low SLV. For soil invertebrates in shallow soil, chromium has HQs greater than 1.0 based on the low SLVs and high SLVs, and the low SLV-based HQ for Total HPAHs is also greater than 1.0.

The robin has HQs greater than 1.0 based on the NOAELs and LOAELs for chromium, lead, nickel, and DEHP in surface soil. In addition to these CPECs, cadmium, mercury, and endrin aldehyde also have HQs greater than 1.0 based on the NOAEL. The CPECs just listed (for surface soil) also have HQs greater than 1.0 in shallow soil for the robin.

The shrew has HQs greater than 1.0 based on the NOAELs and LOAELs antimony, chromium, lead, nickel, and Total HPAHs in surface soil. In addition to these CPECs, cadmium, mercury, and DEHP also have HQs greater than 1.0 in surface soil for the robin based on the NOAEL. The CPECs just listed (for surface soil) also have NOAEL-based HQs greater than 1.0 in shallow soil for the shrew, with the exception of DEHP for which the NOAEL-based HQ is less than 1.0. Chromium, lead, nickel, and Total HPAHs in shallow soil also have LOAEL-based HQs greater than 1.0 for the shrew.

3.1.3 Pistol Range AOPC

Lead was identified as the only CPEC and subsequently as a CEC at the Pistol Range AOPC due to the potential for adverse effects to populations of invertivorous birds or mammals, represented by the robin and shrew. For both the robin and shrew, lead has HQs greater than 1.0 based on both the NOAEL and LOAEL.

3.1.4 Bulb Slope AOPC

While both mercury and lead were identified as CEPCs for the Bulb Slope AOPC, only mercury was identified as a CEC, which is due to its potential for community-level impacts to soil invertebrates. Mercury for soil invertebrates has HQs greater than 1.0 based on both the low SLV and high SLV.

3.1.5 All Four AOPCs Combined

All of the NOAEL- and LOAEL-based HQs and hazard indices (HIs) are less than 1.0 for the wide-ranging receptors (kestrel and mink). Thus, no CECs are identified for the combined AOPCs.

3.1.6 Risk Drivers for Ecological Receptors

A subset of the CECs were identified as being risk drivers for ecological receptors in accordance with guidance from the U.S. Environmental Protection Agency (USEPA 1999). Table 3-2 summarizes the CECs identified as ecological risk drivers along with the rationale for selection or exclusion as a risk driver. Selection of risk drivers for ecological receptors of concern included consideration of the uncertainty in risk estimates based on quantity and quality of exposure and effects data. Generally, those risk estimates with an HQ greater than 1.0 based on the LOAEL/high SLV were considered risk driver chemicals. When the exceedances were minor —

greater than 1.0 but less than 2.0 — the CPECs were further assessed to evaluate the level of uncertainty and conservatism in the estimate. Potential risk drivers were also evaluated in relation to natural background concentrations. Compounds identified as risk drivers are used in development of PRGs, as described in Section 4. CECs not selected as risk drivers in the baseline ERA are evaluated in Section 7.5 to assess the potential for risk reduction following remedial actions. The remaining CECs are also retained for future sampling as part of long term monitoring.

The Landfill AOPC ecological risk drivers identified based on the findings of the risk assessment include **chromium, copper, lead, mercury, nickel, and Total HPAHs**. While chlordane is identified as a CEC for the Landfill APOC, it is not considered an ecological risk driver because the LOAEL-based HQ of 1.6 in surface and shallow soil is considered approximately equal to 1.0 given the inherent level of uncertainty and conservatism built into the ecological risk assessment. As such, no PRG is necessary for chlordane in the Landfill AOPC to guide alternatives formulation.

No ecological risk drivers are identified for the Sandblast AOPC since that portion of the island will remain under industrial use. While ecological receptors will continue to access the Sandblast AOPC, this portion of Bradford Island does not represent suitable wildlife habitat and is actively used for industrial activityby the Bonneville Dam operating project.

No ecological risk driver CECs are identified for the Bulb Slope AOPC. While mercury had a high SLV based HQ of 1.4, it does not constitute an ecological risk driver given the level of conservatism built into the estimate along with the limited occurrence of mercury exceedances in the Bulb Slope AOPC. No PRG for mercury is necessary in the Bulb Slope AOPC.

No risk drivers were elucidated through analysis of all four AOPCs combined.

3.2 Baseline Human Health Risk Assessment

The baseline HHRA evaluated the Landfill, Sandblast Area, Pistol Range, and Bulb Slope AOPCs of the Upland OU. Excess lifetime cancer risks and, if appropriate, noncancer hazards were estimated for the carcinogenic COPCs, for each combination of receptor, exposure medium, and exposure scenario as presented in the RI/FS Work Plan Update (URS, 2014) . For non-carcinogenic chemicals, only noncancer hazards were estimated. The results were summed to provide quantitative estimates of multi-pathway and multi-media risks and hazards for each receptor for the Reasonable Maximum Exposure (RME) scenario. The RME represents relatively conservative, upper-bound reasonable maximum estimates, whereas the Central Tendency Exposure (CTE) estimates provide a range and represent the average exposure. The estimated risks, HQs, and HIs are presented in the context of whether they were:

1) less than the USEPA risk level of 1×10^{-6} (also expressed as one in a million) or HI of 1, whereby risks at or below these thresholds have an insignificant contribution to lifetime excess cancer risk (*i.e., de minimis*);

2) within the USEPA's acceptable risk range of 1×10^{-6} to 1×10^{-4} for cancer and HQ or HI of less than or equal to 1 for noncancer COPCs (USEPA, 1991); or

3) exceeding the USEPA acceptable risk range, i.e., greater than 1×10^{-4} or an HQ or HI greater than 1.0 .

The receptors evaluated include occupational workers and tribal fishing platform users along with children and infant receptors as a component of the tribal fishers. The infant receptor is not standard for risk assessments under CERCLA but was added during the baseline risk assessment at the request of Oregon DEQ. The infant receptor was evaluated as a component of the tribal fishing platform receptor, which is the most sensitive receptor relative to the occupational receptors. Application of the infant receptor to the fishing platform user is considered a conservative risk estimate sufficient to represent risk to infant receptors associated with occupational worker. The occupational scenario followed the EPA's previously established exposure factors as presented in the Exposure Factors Handbook (2011). For the fishing platform scenario, no previously established parameters were available to reasonably represent a scenario of tribal occupancy for purposes of fishing at Bradford Island. As such, conservative exposure parameters, similar to that of a residential scenario, were selected to represent the RME and CTE scenarios. While these are likely conservative exposure estimates, the future scenario for fishing at Bradford Island by tribal members exercising U&A fishing rights is uncertain and can only be estimated. Fishing is not currently occurring from Bradford Island and no specific surveys of tribal fishing at or around Bradford Island have been conducted. Thus, these conservative exposure parameters help to establish RME and CTE scenarios, expected to occur in the future once remedial action reduces risk. After finalization of the baseline HHRA, USACE evaluated additional exposure scenarios based on input from the Technical Advisory Group. The exposure duration for adults associated with the tribal fishing platform was increased from 20 to 64 years. Additional AOPC specific exposure times were also included. A 4 hour/day exposure time for the Sandblast AOPC was evaluated given the assumption that this area, primarily designated for industrial use, could still be transited by tribal fishing platform receptors. A 12 hour/day exposure time for the Landfill AOPC was also evaluated based on the assumption that tribal fishing platform receptors would occupy this area during daylight hours, approximately 12 hours/day. At the time USACE conducted this supplemental analysis, a January 2017 update in EPA's Integrate Risk Information System published decreased toxicity values for benzo(a)pyrene. As such, the updated values for the oral slope factor and inhalation unit risk were included in the analysis. The results of this supplemental analysis are incorporated into this section and included as an addendum to the baseline HHRA (Appendix 1).

ODEQ's acceptable risk thresholds of 1×10^{-6} for individual carcinogens and 1×10^{-5} for multiple carcinogens were also considered (ODEQ, 2010). Individual chemicals associated with risk levels greater than the ODEQ thresholds of 1×10^{-6} or noncancer HQ greater than 1 were identified as COCs, except arsenic because of the relatively elevated background levels, which were also considered.

It is important to note that, since excess lifetime cancer risks are only expressions of likelihood of cancer incidence, and HIs are estimated ratios to safe doses, exceedance of the ODEQ risk thresholds or USEPA acceptable risk range does not automatically mean that adverse effects may have occurred or will occur (e.g., does not automatically mean that the COC will be recommended as a Risk Driver chemical).

Cancer risks are presented to one significant figure and noncancer hazards to two significant figures, in accordance with ODEQ guidance (ODEQ, 2010) .Cancer risks are discussed using 1×10^{-6}, 1×10^{-5}, and 1×10^{-4} conventions.

Table 3-3 summarizes the RME and CTE exposure scenarios for both cancer and noncancer risks for each receptor of concern. The risks presented in Table 3-3 are for the total lifetime excess cancer risks and noncancer hazard indices for all COPCs summed for an individual receptor and exposure media. Cancer and noncancer risks for individual COPCs associated with each receptor and medium can be found in the baseline HHRA (Appendix 1).

3.2.1 Risks Associated with the Occupational Receptor

3.2.1.1 Landfill AOPC

The baseline HHRA evaluated exposures to COPCs in soil and groundwater at the Landfill AOPC. The outdoor maintenance worker exposure to surface soil had RME cancer risk of 6×10^{-5}, which exceeds the ODEQ cancer threshold of 1×10^{-6} but falls within the USEPA's acceptable risk range of 1×10^{-6} to 1×10^{-4}. The noncancer HI was acceptable at 0.02. The primary sources of risk are arsenic and cPAHs.

An evaluation of total, background, and site-related incremental risk was performed. Based on this comparison, arsenic is not considered a COC since the site-related contribution to risk is at acceptable levels (USEPA, 2002a) (USEPA, 2002b).

Incidental ingestion was the only significant exposure route for arsenic, yielding 3×10^{-6} cancer risk, and was based on a surface soil Exposure Point Concentration (EPC) of 10.5 mg/kg. Following USEPA guidance (USEPA, 2002b), the contributions from background arsenic and site-related arsenic were evaluated further. The Reference Area upper prediction limit (UPL) for arsenic is 5.4 mg/kg. Therefore, the incremental risk from site-related arsenic is 1×10^{-6}, which is at the ODEQ threshold.

Ingestion and dermal contact with cPAHs were the significant exposure routes, with the ingestion route yielding approximately twice the risk as dermal contact. Benzo(a)pyrene was the primary contributor to risk among the cPAHs, and its contribution to risk from cPAHs is approximately an order of magnitude greater than any other cPAH or 60% of the risk from cPAHs (6×10^{-5}).

The USEPA adult lead model (ALM) estimated acceptable percent chance of exceeding the target blood lead concentration for the outdoor maintenance worker's exposure to soil. It was also shown that lead in surface and subsurface soil at the site does not pose a threat of unacceptable blood lead concentration levels to fetuses in adult commercial/industrial receptors (no more than a 5% chance of exceeding the 10 micrograms per deciliter (µg/dL) blood lead concentration of concern in women of child bearing age (USEPA, 2003)).

The construction worker exposure to deep soil had a RME cancer risk of 5×10^{-6}, which exceeds the ODEQ threshold of 1×10^{-6} but falls within the USEPA's acceptable risk range of 1×10^{-6} to 1×10^{-4}. The noncancer HI of 1 was at the ODEQ and USEPA threshold, primarily based on inhalation exposure for perchloroethylene (PCE). Due to the dilution and mixing that occur in outdoor situations and since the HI is at the risk threshold, this HI is acceptable and PCE was not selected as a COC. The primary contributor to risk is benzo(a)pyrene through soil ingestion (3×10^{-6}) and dermal contact (1×10^{-6}). No other cPAHs were COPCs for this receptor exposure to deep soil.

The excavation/trench worker RME exposure to contaminants in groundwater yielded cancer risk of 5×10^{-8} and noncancer HI of 0.04. Both are well below acceptable thresholds. This pathway considered incidental ingestion and dermal contact to COPCs in groundwater and inhalation of VOCs that volatilized from the groundwater into trench air. CTE calculations were not performed due to low RME results and because this is a minor exposure pathway.

3.2.1.2 Sandblast Area AOPC

The baseline HHRA evaluated exposures to COPCs in soil, soil gas, and groundwater at the Sandblast Area AOPC. The outdoor maintenance worker exposure to surface soil had RME cancer risk of 1×10^{-5}, which exceeds the ODEQ threshold of 1×10^{-6} but falls within the USEPA's acceptable risk range of 1×10^{-6} to 1×10^{-4}. The noncancer HI was acceptable at 0.07. The primary sources of risk are arsenic and cPAHs.

An evaluation of total, background, and site-related incremental risk was performed, similar to the evaluation for Landfill AOPC soils. Based on this comparison, arsenic is not considered a COC since the site-related contribution to risk is at acceptable levels (USEPA, 2002a) (USEPA, 2002b).

Ingestion and dermal contact of cPAHs were the significant exposure routes with the ingestion route yielding approximately twice the risk as dermal contact. Risk from benzo(a)pyrene was about double that of benzofluoranthenes, total, and the overall cPAHs yielded a risk of 1×10^{-5}. Benzo(a)pyrene was detected consistently throughout the surface soil of the Sandblast Area AOPC (36 detections out of 40 samples) with an EPC of 2.4 milligrams per kilogram (mg/kg).

For both available surface soil depth ranges, the USEPA ALM estimated acceptable percent chance of exceeding the target blood lead concentration for the outdoor maintenance worker due to exposure to surface soil. Similar to the Landfill AOPC, it was shown that lead in surface and subsurface material at the Sandblast Area AOPCC does not pose a threat of unacceptable blood lead concentration levels to fetuses in adult commercial/industrial receptors.

The construction worker exposure to sub-surface soil had a RME cancer risk of 2×10^{-6}, which exceeds the ODEQ threshold of 1×10^{-6} but falls within the USEPA's acceptable risk range of 1×10^{-6} to 1×10^{-4}. The noncancer HI was acceptable at 1. The primary contributor to risk is benzo(a)pyrene, with a cumulative multi-pathway cancer risk of 2×10^{-6}. No other cPAHs were COPCs for this receptor exposure to sub-surface soil.

The excavation/trench worker RME exposure to contaminants in groundwater yielded cancer risk of 1×10^{-7} and noncancer health hazard of 0.7. Both are below ODEQ and USEPA risk thresholds. This pathway considered incidental ingestion and dermal contact to COPCs in groundwater and inhalation of VOCs, which volatilized from the groundwater into trench air. CTE calculations were not performed due the low RME results and because this is a minor exposure pathway.

The vapor intrusion pathway was considered for both current and potential future indoor exposures in an occupational setting. The approach included risk estimation based on modeled estimates of indoor air concentrations using soil gas data as well as a review of other site data and information. The multiple lines of evidence suggest a localized historic source of VOCs in the vicinity of the current Hazardous Materials Storage Unit. The source area and the associated plumes appear to be undergoing degradation, and vapor intrusion-related risks are at acceptable levels both for occupants of current buildings and for future buildings.

3.2.1.3 Pistol Range AOPC

No COPCs were identified in the RI for the occupational receptor.

3.2.1.4 Bulb Slope AOPC

No COPCs were identified in the RI for the occupational receptor.

3.2.2 Risks Associated with the Fishing Platform Receptor

3.2.2.1 Landfill AOPC

The baseline HHRA evaluated exposures to COPCs in soil at the Landfill AOPC. The fishing platform user exposure to current surface soil concentrations resulted in a RME risk of 1 x 10^{-3} and HI of 1 based on a 26 year exposure duration and 24 hours/day exposure time. Cancer risks exceeded the USEPA acceptable risk range of 1x10^{-4} to 1x10^{-6}. The primary contributors to risk were the cPAHs (primarily benzo(a)pyrene), with minor contributions from arsenic.

The noncancer hazard was at the noncancer threshold value of 1 based on a 26 year exposure duration and 24 hours/day exposure time. No single chemical exceeded a HQ of 1. The greatest relative contributions to hazard came from total PCBs, arsenic, and mercury, although their individual HQs were less than 0.5. The target organs and effects associated with the noncancer effects of these chemicals vary widely and are unlikely to result in cumulative effects. For example, arsenic may primarily affect the skin (hyperpigmentation, keratosis), mercury may affect the kidney (auto-immune effects), and PCBs may affect ocular glands (exudates) and digits (distorted fingers and toes) (USEPA, 2015). Based on the low potential for toxicity to individual target organs and an HI equal to the threshold, risk is considered insignificant.

Following USEPA guidance (USEPA, 2002b), the contribution from background arsenic and site-related arsenic were evaluated further. The Reference Area UPL for arsenic is 5.4 mg/kg, which is almost half of the arsenic EPCs for both the Landfill and Sandblast Area AOPCs. Therefore, the incremental risk from site-related arsenic is 1 x 10^{-5}, which exceeds the ODEQ threshold, but falls within the USEPA acceptable risk range.

Benzo(a)pyrene was the primary contributor to risk among the cPAHs, and its contribution to risk from cPAHs is approximately an order of magnitude greater than any other cPAH or 60% of the risk from cPAHs (6 x 10^{-5}), based on a 26 year exposure duration, 24 hours/day exposure time, and the previous toxicity values for benzo(a)pyrene prior to the January 2017 revision. Benzo(a)pyrene was detected consistently throughout the surface soil of the Landfill AOPC (31 detections out of 33 samples) with the EPC being 11.2 mg/kg as compared to the Reference Area 95% UPL of 0.037 mg/kg. The Reference Area UPL for all cPAHs was 0.051 mg/kg benzo(a)pyrene-equivalent carcinogenic potency. Overall, background concentrations contribute a very small fraction to overall risk.

The nursing infant receptor was evaluated for this receptor using the (ODEQ, 2010) infant risk adjustment factor, as detailed in Section 2.4.7 of the baseline HHRA (Appendix 1). The RME nursing infant cancer risk was acceptable at 1 x 10^{-6} but had an HI of 2, or slightly greater than the threshold, based on PCB exposure.

Based on the lead evaluation, the probability of exceeding the target blood lead levels for the fishing platform user who may be exposed to Landfill soils was not a concern.

The supplemental evaluation of the tribal fishing platform receptor evaluated an exposure duration 70 years (64 years for an adult plus 6 for child) and exposure time of 12 hours/day in the Landfill

AOPC. The decreased slope factor and inhalation unit risk for benzo(a)pyrene was also applied. The lifetime total excess cancer risk decreased to 4.3 x 10^{-4} for cPAHs. Non cancer hazard estimates increased slightly to a HQ of 3.0 for the child, 2.5 for the adult, and 1.5 for the nursing infant pathway.

3.2.2.2 Sandblast Area AOPC

The baseline HHRA evaluated exposures to COPCs in soil at the Sandblast Area AOPC. The fishing platform user exposure to current surface soil concentrations had a RME risk of 3 x 10^{-4} and HI of 1.8 based on a 26 year exposure duration and 24 hours/day exposure time. At the Sandblast Area AOPC, cancer risks also exceeded the USEPA acceptable risk range. Noncancer hazards were at or slightly higher than 1. COCs contributing to risk were similar to those for Landfill soils, consisting primarily of cPAHs, but with minor contributions from more chemicals, including arsenic, total PCBs, and DEHP. No individual COPC had a HQ greater than 1, but the cumulative evaluation resulted in a total HI of 2 due to arsenic, nickel, Total PCBs, PCE, and trichloroethylene (TCE). Similar to the noncancer chemicals at the Landfill, the target organs and effects associated with these chemicals are also variable. In addition to the previously described arsenic and PCBs, nickel may result in generalized decreased body weight, PCE may affect the nervous system (neurotoxicity), and TCE may affect the thymus gland (decreased weight), vascular system (decreased plaque cell-forming response), and heart (cardiac malformation) (USEPA, 2015). Based on the low potential for toxicity to individual target organs, the marginal HI of 2 is considered acceptable.

The nursing infant receptor was evaluated for the fishing platform user using the infant risk adjustment factor, as detailed in Section 2.4.7 of the Baseline HHRA. As presented in (ODEQ, 2010), the nursing infant cancer risk was acceptable at 1 x 10^{-6} and had an HI of 2, slightly greater than the threshold of 1, based on PCB exposure.

The supplemental evaluation of the tribal fishing platform receptor evaluated an exposure duration for adults of 64 years and exposure time of 4 hours/day in the Sandblast AOPC. The decreased slope factor and inhalation unit risk for benzo(a)pyrene was also applied. The lifetime total excess cancer risk decreased to 2.9 x 10^{-5} for cPAHs. Non cancer hazard estimates decreased for the adult, child, and nursing infant pathway, with all HQs below 1.0.

3.2.2.3 Pistol Range AOPC

Lead was the only COPC identified at the Pistol Range AOPC and only for the fishing platform user receptor.

The ALM predicted that a typical fetus of an adult receptor exposed to lead in soil at the Pistol Range AOPC would have 0.033% of the chance of the blood lead concentration exceeding 10 µg/dL. Therefore, lead does not pose an unacceptable threat to fetuses of adult receptors exposed to soil or sediment in the Pistol Range AOPC (no more than a 5% chance of exceeding the 10 µg/dL blood lead concentration (USEPA, 2013)).

The Integrated Exposure Uptake Biokinetic model (IEUBK) predicted that a typical child receptor exposed to lead in soil at the site would have an approximate 0.34% chance of the blood lead concentrations exceeding 10 µg/dL. The blood lead concentration prediction is well below USEPA's target to limit the risk to a typical child to no more than a 5% chance of exceeding the 10 μg/dL blood lead concentration (USEPA, 1994). Therefore, lead does not pose an unacceptable threat to child receptors exposed to soil in the Pistol Range AOPC.

3.2.2.4 Bulb Slope AOPC

Lead was the only COPC identified at the Bulb Slope AOPC and only for the fishing platform user receptor.

The ALM predicted that a typical fetus of an adult receptor exposed to lead in soil at the site would have 0.038% of the chance of the blood lead concentration exceeding 10 μg/dL. Therefore, lead does not pose a threat to fetuses of adult receptors exposed to soil in the Bulb Slope AOPC.

The IEUBK predicted that a typical child receptor exposed to lead in soil at the site would have an approximate 0.45% chance of the blood lead concentrations exceeding 10 μg/dL. The blood lead concentration prediction is well below USEPA's target to limit the risk to a typical child to no more than a 5% chance of exceeding the 10 μg/dL blood lead concentration (USEPA, 1994). Therefore, lead does not pose an unacceptable threat to child receptors exposed to soil in the Bulb Slope AOPC.

3.2.3 Risk Drivers for Human Health Receptors

For the Landfill AOPC, **cPAHs** are the only risk driver COC. Total PCBs as aroclors and arsenic were also identified as COCs. However, because the lifetime excess cancer risk for these two COCs fell within EPA's acceptable risk range of 1×10^{-4} to 1×10^{-6}, they are not identified as risk drivers in the Landfill AOPC. Thus, PRGs to address risk reduction for PCBs and arsenic are not included.

No risk drivers were identified for the Sandblast AOPC. All occupational receptors have risks that fall within EPA's acceptable risk threshold of $1x10^{-4}$ and $1x10^{-6}$. For the tribal fishing platform scenario, the supplemental risk calculations to assess an adult exposure duration of 64 years and exposure time of 4 hours/day, as well as incorporation of decreased toxicity values for benzo(a)pyrene, found risks that fall within EPA's acceptable risk threshold of $1x10^{-4}$ and $1x10^{-6}$. As such, no remedial action is warranted for the Sandblast AOPC. No COCs were identified for the Bulb Slope or Pistol Range AOPCs. As such, no risk drivers are present in those areas and PRGs associated with human health are not needed to address risk reduction in the two AOPCs.

Table 3-4 summarizes which COCs were selected as risk drivers along with the rationale for selection or exclusion. Those COCs selected as risk drivers will be carried forward for development of PRGs to guide alternatives formulation. COCs not selected as risk drivers in the baseline HHRA are included in long term monitoring and evaluated in Section 7.5 to assess the potential for risk reduction following remedial actions.

3.3 Risk-based Threshold Concentrations

3.3.1 Soil RBTCs for Ecological Receptors

To aid in risk interpretation and support development of PRGs, site-specific RBTCs were derived for each AOPC and wildlife receptor for the CECs with HQs greater than 1.0 based on LOAEL TRVs. All LOAEL-based HQs were less than 1.0 for the kestrel and mink; therefore, RBTCs were only calculated for the robin and shrew. By selecting the most sensitive receptors to derive the

RBTCs, it is likely that the other receptor groups would also be protected. The following equation was used to calculate the RBTCs for the robin and shrew:

$$\text{Site Specific RBTC} = \frac{TRV \times BW}{\left[\left(IR_{food} \times BAF\right) + IR_{soil}\right]}$$

where:

RBTC	=	Site-specific risk-based threshold concentration for soil (mg chemical per kg soil dry weight)
TRV	=	LOAEL-based TRV (mg chemical ingested per kg BW per day)
BW	=	Body weight (kg)
IR_{food}	=	Ingestion rate of food, as represented by soil invertebrate tissue (kg dry weight food per day)
BAF	=	Soil to terrestrial invertebrate bioaccumulation factor (kg soil per kg tissue)
IR_{soil}	=	Ingestion rate of soil (kg dry weight soil per day)

The exposure factors for the robin and shrew used in this equation are presented in Tables 3-5 and 3-6, respectively, and the LOAEL TRVs are presented in Table 3-7. Due to the low contribution of water ingestion to the overall dose for these receptors (less than 5%, but varies by CPEC), this pathway was not included in the RBTC calculations. The final site-specific RBTCs for each receptor are presented in Table 3-8. Additionally, Table 3-8 presents the high SLVs for plants and/or soil invertebrates per AOPC for the CECs with high-SLV based HQs greater than 1.0.

3.3.1.1 Landfill AOPC

The northwestern section of the Landfill, primarily within and around the Gully Test Pit and Lead Hot Spot Test Pit #1, is the most impacted area of this AOPC with co-occurrences of most CECs. In addition, the most impacted area of the Landfill for mercury is the Mercury Vapor-Lamp Test Pit and one isolated spot northeast of the Pesticide/Herbicide Wash Area (Figure 3-1). These areas of the Landfill will be further evaluated as discussed in Section 4.

3.3.1.2 Sandblast AOPC

The most co-occurring exceedances of the RBTCs occur within the Spent Sandblast Grit Disposal Area, which basically encompasses the Current Hazardous Materials Storage Area, the northern boundary of the Former Hazardous Materials Storage Area, and around Catch Basin #1. In addition, concentrations of chromium and nickel greater than background, lead, and HPAHs are above the RBTC within the Equipment Laydown Area (Figure 3-2).

3.3.1.3 Pistol Range

The highest concentrations of lead, including the maximum concentration that was detected below the surface, were detected at and behind the approximate location of the backstop. Twenty additional locations have concentrations above the RBTC in addition to the location with the maximum detection. In addition to the area surrounding the backstop, these locations also occur north and east of the approximate location of the Former Firing Shed (Figure 3-3).

3.3.1.4 Bulb Slope

The maximum concentration of mercury was detected in a sample collected from Pile #3, Bank #4, which is located near the southwestern boundary of the Bulb Slope, i.e., up-gradient and away from the boundary closest to the Columbia River. The remaining two samples with exceedances of the RBTC for soil invertebrates were also collected from the southern boundary of this AOPC. All three samples with mercury above the RBTC are bound by samples with concentrations below the RBTC collected down-gradient of the slope, closest to the river (Figure 3-4).

3.3.2 Soil RBTCs for the Human Health Receptors

To aid in risk interpretation and support development of PRGs, RBTCs were calculated for the COCs (identified from the list of COPCs) for each receptor, corresponding to a target cancer risk level of 1×10^{-6} (Table 3-9).

The equation for calculating RBTCs is as follows:

RBTC = EPC x Target Risk / Calculated Risk

where:

RBTC = Risk Based Threshold Concentration

EPC = EPC for Chemical from Baseline HHRA

Target Risk for individual PAHs and cumulative cPAHs = 1×10^{-6}

Calculated Risk = Chemical Specific from Baseline HHRA

3.3.2.1 Landfill AOPC

cPAHs were identified as the only COC for occupational exposures. Concentrations exceeded the occupational RBTC for cPAHs at the Landfill in the 0-3 ft and 3-10 ft bgs depths (Figure 3-5). The locations were at the northwestern section of the Landfill, primarily within and around the Gully Test Pit and Lead Hot Spot Test Pit #1, Mercury Vapor-Lamp Test Pit, far eastern portion of the Landfill, and one isolated spot northeast of the Pesticide/Herbicide Wash Area.

For the fishing platform user under current conditions, arsenic, Total PCBs, and cPAHs were identified as the COCs. The RBTCs for the fishing platform receptor were exceeded in the shallow soils at the Landfill, primarily for cPAHs (Figure 3-6). Exceedances of the RBTCs for arsenic and PCBs were co-located with the cPAH exceedances.

The supplemental risk analysis conducted for the tribal fishing platform receptor to assess additional exposure scenarios and incorporate the decreased toxicity value for benzo(a)pyrene also include calculation of RBTCs. Most notably, the RBTC for cPAHs increased to 0.073 mg/kg relative to the RBTC of 0.015 mg/kg presented in the baseline HHRA (Appendix 1).

3.3.2.2 Sandblast AOPC

cPAHs were identified as the only COC for occupational exposures to soil at the Sandblast Area AOPC (Section 2.7 of the baseline HHRA (Appendix 1). Concentrations exceeded the occupational RBTCs at the Sandblast Area AOPC in the shallow and deeper soils (Figure 3-7). The locations are at the Erodible Unit, Current Hazardous Materials Storage Area, Equipment Laydown Area, and the Former Hazardous Materials Storage Area. All exceedances were in the shallow soils (0-3 ft bgs) with the exception of a single location near the Current Hazardous Materials Storage Area that exceeded both the outdoor worker and construction worker RBTC.

For the fishing platform user under current conditions, the COCs included arsenic, cPAHs, DEHP, and Total PCBs (Section 2.7 of the Baseline HHRA). Relative to the occupational exceedances (Figure 3-7), there are more locations with fishing platform exceedances (Figure 3-8) including near the Catch Basin #1 and the Former Hazardous Materials Storage Area. The organic COCs (PCBs, DEHP, and cPAHs) exceedances are generally co-located.

Again, the supplemental risk analysis conducted for the tribal fishing receptor saw an increase in the RBTC for cPAHs. The RBTC for cPAHs from the supplemental risk analysis was 0.22 mg/kg. The RBTC for cPAH calculated in the baseline HHRA was 0.015 mg/kg.

3.4 Key Findings of the Baseline Risk Assessments

The Ecological and Human Health Baseline Risk Assessments build on the process initiated in the RI to identify COIs and COPCs/CPECs. COIs were initially defined in the RI based on detection frequency and maximum detection above background concentrations (for inorganics only). These COIs were then screened during the RI in a screening level risk assessment that incorporated both EPA and ODEQ screening guidance for human health and ecological risk. The results of this screening level risk assessment yielded a suite of COPCs/CPECs that were carried forward to the baseline risk assessments. In addition to the COPCs identified in the RI, additional COPCs were included to account for addition of the tribal fishing receptor prior to initiating the baseline risk assessment. The baseline risk assessments, with key findings summarized in the previous sections, identified COCs/CECs based on whether contaminants had a HQ greater than 1 or cancer risk greater than $1x10^{-6}$. As part of this FS, COCs/CECs were further refined into contaminants that are outside EPA's Risk Management Range of $1x10^{-4}$ to $1x10^{-6}$. Those contaminants that are greater than the threshold of $1x10^{-4}$ are identified as risk drivers, and are used to set PRGs and guide the alternatives formulation. Figure 3-9 illustrates this process used to identify and screen contaminants as COIs, COPCs/CPECs, COCs/CECs, and risk drivers.

3.4.1 Ecological Risks

Table 3-10 summarizes the CECs for each AOPCs identified through the baseline ERA as well as the risk drivers for which PRGs (Section 4) are warranted. No further action at the Bulb Slope is warranted based on the low risk estimates. No further action is also warranted for the Sandblast AOPC, given the industrial use of the area contributing to suboptimal habitat and low impact on community and population levels for receptors. Remedial action is warranted for the two remaining AOPCs based on multiple exceedances of RBTCs for one or more ecological receptors.

The site-specific RBTCs were used to identify the areas within each AOPC that may, depending on the development and selection of a final alternative, be the focus of remedial action. These areas are summarized as follows:

Landfill AOPC – northwestern section of the Landfill, primarily within and around the Gully Test Pit and Lead Hot Spot Test Pit #1, Mercury Vapor-Lamp Test Pit, and two locations within and northeast of the Pesticide/Herbicide Wash Area (Figure 3-1).

Pistol Range AOPC – around the approximate location of the backstop, and north and east of the approximate location of the Former Firing Shed (Figure 3-3).

3.4.2 Human Health Risks

COCs are identified based on RME results exceeding the ODEQ cancer risk threshold of 1×10^{-6} cancer risk. Table 3-9 lists the RBTCs and Reference Area UCLs (if available) for the COCs for the Landfill and Sandblast Area AOPCs. Risk driver COCs for which PRGs are warranted are also identified in Table 3-9. Risk drivers are generally based on exceedance of the USEPA acceptable risk range of 1×10^{-4} to 1×10^{-6}, as well as other risk management considerations.

Media evaluated for the Landfill AOPC and Sandblast Area AOPC included soil and groundwater. In addition, soil gas data were also evaluated at the Sandblast Area AOPC. Risk assessment findings were similar for both AOPCs. Exposure to shallow soil for the outdoor maintenance worker and to deeper soil for the construction worker showed RME and CTE cancer risks within the USEPA acceptable risk range of 1×10^{-6} to 1×10^{-4}. RME risks from exposure to deeper soils for construction workers were also within the USEPA acceptable risk range. RME risks related to trench worker exposure to groundwater were *de minimis* (less than 1×10^{-6}). At the Sandblast Area AOPC, RME and CTE risks related to soil gas were also *de minimis*.

At both the Landfill AOPC and the Sandblast Area AOPC, RME and CTE cancer risks exceeded the USEPA acceptable risk range for the fishing platform receptors from exposure to shallow soils under current conditions. However, under the supplemental risk analysis for the fishing platform receptor, assuming a 4 hour/day and 64 year adult exposure duration, cPAH cancer risk fell with the USEPA acceptable risk range. cPAHs were the primary COCs. Risks and noncancer hazards for nursing infants were generally close to or less than 1×10^{-6} for PCBs under current conditions.

At the Pistol Range and Bulb Slope AOPCs, which were evaluated only for the newly added fishing platform users, lead concentrations were at acceptable levels under current conditions for exposure to soil and lagoon sediment at the Pistol Range and soil at the Bulb Slope.

3.5 Cumulative Risk Considerations

Cumulative risk for both ecological and human health was generally evaluated from a qualitative perspective, taking into account conservatism and uncertainty in both the baseline ERA and the baseline HHRA.

For each receptor within an individual AOPC, multi pathway exposure was evaluated for human health risk. Cancer and noncancer risks was summed for each COPC based on ingestion, inhalation, and dermal exposure. Further, risk was also summed across all COPCs, incorporating multi-pathway exposure, providing an estimate of total cancer and noncancer risk for each AOPC and receptor. For the Landfill AOPC, this resulted in an RME cumulative cancer risk of 1.2×10^{-3} for the tribal fishing platform receptor across all exposure pathways for all carcinogenic COPCs. cPAHs accounted for 98% of this total risk. Arsenic accounts for 1% of the total risk and total PCBs and Naphthalene were each less than 1% of the total risk. For total PCBs in the Landfill AOPC, risk was within at CERCLA risk management range, at 1.7×10^{-6} for the tribal fishing receptor. The supplemental risk analysis to account for different exposure duration and time, as well as the changed toxicity value or benzo(a)pyrene, altered these percent contributions slightly and generally decreased overall risk.

Ecological risk is calculated differently than human health risk, in that exposure is not separated by exposure pathway, but rather addressed in terms of total contact. Hazard Indices were calculated for each receptor and AOPC, summing the Hazard Quotients across each individual

CPEC to obtain an overall risk per AOPC. Ecological risk was further evaluated by combining all four AOPCs for the wide-ranging receptors (kestrel and mink). For this scenario, all of the NOAEL- and LOAEL-based HQs and HIs are less than 1.0.

For evaluating cumulative risk associated with exposure from both the River and Upland OUs, it is important to consider the contrasting risk drivers for each OU. For human health in the Upland OU, the risk driver is cPAHs. In contrast, for the River OU the primary human health risk driver is total PCBs. As stated previously, total PCBs contributed less than 1% to the overall risk in the Landfill and Sandblast AOPCs for the fishing platform receptor. These percentages Cumulative exposure from the Upland OU for total PCBs in negligible relative to the risk associated with exposure to total PCBs in the River OU. Ecological risk drivers are also different between the River and Upland OUs, with metals driving risk in the Upland OU and total PCBs driving risk in the River OU. The only overlapping risk driver is HPAHs. While quantitative evaluations of risk were conducted separately for these OUs, a qualitative evaluation of the two OUs demonstrates that cumulative risks will be managed accordingly through each OU's remedial actions.

Further discussion of how cumulative risk is accounted for in establishing PRGs is presented in Section 4.3.6 of this FS.

3.6 To Be Considered (TBC) Considerations

In conjunction with the findings of the baseline risk assessments, To Be Considered (TBC) criteria are incorporated with the findings of the baseline risk assessments to make risk management decisions. TBCs are not considered ARARs, and have different bearing on PRG establishment (Section 4).

Oregon DEQ's *Guidance for Identification of Hot Spots* (ODEQ, 1998) is incorporated as a TBC for this feasibility study. Implementation of the hot spot analysis incorporates the RBTCs developed as part of the risk assessment to determine if additional remediation beyond that required to achieve PRGs is warranted and feasible.

Additionally, regional background values for inorganics in soil established by Oregon DEQ is incorporated into development of PRGs. Additional discussion of regional background considerations is provided in Section 4.3.3.

3.7 Land Use Considerations

As part of the feasibility study and following development of the baseline risk assessments, it was acknowledged that the Sandblast AOPC is and will remain an active area for operational support to the Bonneville Dam project. Presently, several key operational features occur within the boundaries of the Sandblast AOPC, including: the current hazardous materials storage area, equipment shop, areas for equipment laydown and inspection, refuse receptacles, and vehicle traffic associated with various activities. As such, USACE determined that this area will remain an active area in support of the Bonneville Dam Project. While the tribal fishing receptor was evaluated in the baseline risk assessment for residential like exposure at the Sandblast AOPC, future land use will likely be significantly less, as it will remain a functional component of the Bonneville Dam project. As such, USACE conducted the supplemental risk analysis after finalization of the baseline HHRA to account for a lower exposure time representative of a tribal fishing platform receptor accessing the Sandblast AOPC 4 hours/day to transit through to other portions of the island. Under this limited exposure time, risk falls within the USEPA acceptable risk range of 1×10^{-4} to 1×10^{-6}. Risk for occupational receptors in the Sandblast AOPC fall within the USEPA acceptable risk range of 1×10^{-4} to 1×10^{-6}, and therefore action is not warranted. In regards to ecological risk, given the light industrial use of the area for the project, the Sandblast AOPC does not function as suitable wildlife habitat. Further, since no Threatened and Endangered Species are present in the Upland OU, population and community level effects can be considered in deciding the need for remedial action. Since contamination in the Sandblast OU is not expected to have deleterious effects on community or population level receptors, remediation for ecological risk in unwarranted.

Future land use for areas outside the Sandblast AOPC, including the Landfill, Bulb Slope, and Pistol Range AOPCs, is considered available for tribal fishing and likely not subject to industrial activities associated with the Bonneville Dam project. There are also intentions to manage portions of Bradford Island as future wildlife habitat, particularly for Canadian Geese, as outlined in the Bonneville Master Plan for East Bradford Island Management Unit (USACE, 1997). These future land use consideration warrant development of RAOs and PRGs for both human health, driven by the tribal fishing receptor, and ecological health.

3.8 References

ODEQ. (1998). *Guidance for Identification of Hot Spots. April*.

ODEQ. (2010). *Human Health Risk Assessment Guidance. Final. October.*

URS. (2012). *Remedial Investigation Report: upland and river operable units. Bradford Island, Cascade Locks, Oregon.*

URS. (2014). *Update to Risk Assessment Work Plan for the Upland OU. Bradford, Island, Bonneville Dam Forebay, Cascade Locks, Oregon.* April.

USACE. (1997). Bonneville Master Plan for East Bradford Island Management Unit

USEPA. (1989). *Superfund Risk Assessment Guidance for Superfund, Volume I Human Health Evaluation Manual (Part A), Interim Final. .* EPA/540/1-89/002. December.

USEPA. (1991). *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual. Part B, Development of Risk-Based Preliminary Remediation Goals. Interim.*

USEPA. (1992). *Supplemental Guidance to RAGS – Calculating the Concentration Term. OSWER 9285.7-081.* May.

USEPA. (1994). *Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities. .* OSWER Directive 9355.4-12. July.

USEPA. (1999). *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Peer Review Draft.* Office of Solid Waste and Emergency Response. EPA530-D-099-011A. October.

USEPA. (2002a). *Role of Background in CERCLA Cleanup Program.* OSWER 9285.6-07P.

USEPA. (2002b). *Guidance for Comparing Background and Chemical Concentrations in Soil at CERCLA Sites.* USEPA 540-R-1-003. OSWER 9285.7-41. September.

USEPA. (2003). *Human Health Toxicity Values in Superfund Risk Assessments. .* OSWER Directive 9285.7-53. Solid Waste and Emergency Response. December.

USEPA. (2011) *Exposure Factors Handbook 2011 Edition (Final)*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/052F, 2011.

USEPA. (2013). *ProUCL Version 5.0.00 (Software). Retrieved from http://www.epa.gov/osp/hstl/tsc/software.htm. September.*

USEPA. (2015). *Integrated Risk Information System (IRIS). On-line database. Toxicological Summaries. .*

4 Remedial Action Objectives and Preliminary Remediation Goals

This section of the feasibility study (FS) identifies narrative remedial action objectives (RAOs) and numerical preliminary remediation goals (PRGs) for cleanup of the Bradford Island Upland Operable Unit (OU). RAOs for the Upland OU describe what a proposed cleanup remedy is expected to accomplish to protect human health and the environment (USEPA, 1999). PRGs are the contaminant endpoint concentrations or risk levels associated with each RAO that are believed to be sufficient to protect human health and the environment based on available site information (USEPA, 1997).

The step of identifying narrative RAOs provides a transition between the findings of the human health and ecological risk assessments and development of remedial alternatives in the FS. The RAOs pertain to the specific exposure pathways and receptors evaluated in the risk assessments and for which unacceptable risks were identified.

PRGs are intended to protect human health and the environment and to comply with applicable or relevant and appropriate requirements (ARARs) for specific contaminants (USEPA, 1991). For the Upland OU, PRGs are numerical concentrations or ranges of concentrations in soil that would protect a particular receptor from exposure to a hazardous substance by a specific pathway. The PRGs are expressed as soil concentrations for the identified risk drivers because the alternatives in this FS address cleanup of contaminated soils. The RAOs, ARARs, and PRGs presented here may be modified and will be finalized by USACE in the Record of Decision (ROD).

4.1 Development of Remedial Action Objectives

The RAOs are narrative statements of the medium-specific or area-specific goals for protecting human health and the environment. RAOs describe in general terms what the soil cleanup will accomplish for the Upland OU. RAOs help focus the development and evaluation of remedial alternatives and form the basis for establishing PRGs.

The National Contingency Plan (40 CFR 300.430.(e)(2)(i) states "to establish remedial action objectives specifying contaminants and media of concern, potential exposure pathways, and remediation goals. Initially, preliminary remediation goals are developed based on readily available information, such as chemical specific ARARs or other reliable information."

Section 2 provides a summary of the RI, including the chemical and physical conceptual site model. Section 3 provides summarized results of the risk assessments (both human health and ecological), which identified receptors, exposure pathways, risk drivers and, where calculable, RBTCs. The RAOs presented here were crafted based on the RI and findings from the baseline risk assessments.

RAOs are developed herein for cleanup of contaminated soil at the Bradford Island Upland OU. While groundwater and soil vapor were identified as media with COIs during the Remedial Investigation (RI), all risks from groundwater and soil vapor for the relevant receptors were found to display a lifetime excess cancer risk below 1×10^{-6} or a HI below 1. Because these risks are considered *de minimis*, no remedial action is warranted for groundwater or soil vapor in the Upland OU.

4.1.1 Remedial Action Objectives for the Bradford Island Upland Operable Unit

The results of the baseline HHRA and ERA indicate that remedial action is warranted to reduce unacceptable human health and ecological risks posed by COCs and CECs in Bradford Island Upland OU soils. Unacceptable risks were estimated for certain human health exposure scenarios (through dermal contact and incidental ingestion) and for certain ecological risks (for terrestrial plants, invertebrates, and other ecological receptors).

For human health, EPA defines a generally acceptable risk range (i.e., the "target risk range") for lifetime excess cancer risks as between one in ten thousand (1×10^{-4}) and one in one million (1×10^{-6}),and for non-cancer risks an HI of 1 or less is considered acceptable (EPA 1991a). Excess cancer risks greater than 1×10^{-4} or HIs greater than 1 generally warrant a response action (USEPA, 1997). Thus, any COCs or CECs with an excess cancer risk less than 1×10^{-4} or a non-cancer hazard less than 1 were not considered for remedial action and no corresponding PRG was developed.

Based on guidance provided under CERCLA and other requirements provided by the ODEQ, two RAOs have been identified for the cleanup of Upland OU soils. These RAOs address risk drivers identified in Section 3 of this FS. These risk drivers are a subset of the COCs and CECs determined to pose the greatest level of risk, either based on the degree of certainty in the risk estimation or because the risk is greater than EPA's threshold of 1×10^{-4} for lifetime excess cancer risk. These RAOs are identified below.

RAO1: Reduce to acceptable levels the exposure risk of the fishing platform user to soils contaminated with cPAHs.

RAO2: Reduce to acceptable levels the exposure risk of ecological receptors to soils contaminated with chromium, copper, lead, mercury, nickel, and total HPAHs.

4.2 Applicable or Relevant and Appropriate Requirements (ARARs)

ARARs are defined as any legally applicable or relevant and appropriate standard, requirement, criterion, or limitation under any federal environmental law, or promulgated under any state environmental or facility siting law that is more stringent than the federal law. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, as amended by the Superfund Amendment and Reauthorization Act) Section 121(d) requires remedial actions to achieve (or to formally waive) ARARs.

The CERCLA implementing regulation, the National Contingency Plan (NCP; 40 Code of Federal Regulations [CFR] 300.5) (USEPA, 2002) defines applicable requirements as those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. A requirement may not be applicable, but nevertheless may be relevant and appropriate. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

There are three types of ARARs described here: chemical-specific, action-specific, and location-specific. Chemical-specific ARARs prescribe minimum numerical requirements or standards for cleanup of specific contaminants in specific media such as chromium in soil. During the FS, chemical-specific ARARs are considered in the development of PRGs, which are used to compare protectiveness and effectiveness of the alternatives. Action-specific ARARs place requirements or limitations on actions that may be undertaken as part of a remedy and, during the FS, are used to assure that the alternatives formulation recommends appropriate remediation strategies. Location-specific ARARs are restrictions that could be placed upon the implementation of remedial activities because of geographical, biological, historical, or cultural features at the site. Examples of possible site features that may induce location-specific ARARs include cultural or historical areas, wetlands, flood plains, other ecologically sensitive ecosystems, and geologically active areas.

Tables 4-1 through 4-2 list potential Federal and State ARARs for the Bradford Upland OU.

4.3 Process for Development of Preliminary Remediation Goals

PRGs are the COC or CEC endpoint concentrations initially identified for each RAO that are believed to be sufficient to protect human health and the environment based on available site information (USEPA, 1997). The PRGs are used in the FS to guide the development and evaluation of proposed soil remedial alternatives. PRGs are not final cleanup levels and standards. USACE will select final cleanup levels and standards in the ROD.

PRGs are developed in this subsection for each risk-driver COC or CEC, and are expressed as soil concentrations that are intended to achieve the corresponding RAO. PRGs are based on considering the following factors:

ARARs

RBTCs based on the HHRA and ERA

Background concentrations if protective RBTCs are below background concentrations

Analytical PQLs if protective RBTCs are below concentrations that can be quantified by chemical analysis.

This section presents the numerical criteria in these categories to enable a comprehensive analysis and identification of PRGs. The pertinent information is then compiled and numerical PRGs are identified for each risk driver and each RAO.

4.3.1 Role of ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

4.3.2 Role of RBTCs

As part of the baseline risk assessments (Appendix 1) provided in conjunction with this FS, site-specific soil RBTCs for each of the risk-driver COCs and CECs were developed. RBTCs for human health were calculated based on risks associated with direct soil contact. RBTCs for wildlife receptors were calculated based on ingestion of prey, surface water, and soil.

cPAHs were identified as the risk drivers for the human direct contact pathway for the fishing platform using the 12 hours/day exposure time calculated as part of the supplemental risk analysis. Within the Landfill AOPC a soil RBTC for cPAHs was calculated for the 1×10^{-6} excess cancer risk level and applied as a 95% UCL concentration.

For ecological receptors, soil RBTCs were calculated for, chromium, copper, lead, mercury, nickel, and total HPAHs. Within each relevant AOPC the RBTC for each CEC was applied as a 95% UCL concentration.

4.3.3 Role of Background Concentrations

Under both CERCLA and Oregon DEQ guidance background hazardous substance concentrations are considered when formulating PRGs. Both recognize that setting numerical cleanup goals at levels below background is impractical because of the potential that areas cleaned up to levels below background, because they are surrounded by background levels of contamination, could be recontaminated to levels equaling the background concentrations.

According to both CERCLA and Oregon DEQ guidance, natural background refers to substances that are naturally present in the environment in forms that have not been influenced by human activity (e.g., naturally occurring metals) (ODEQ, 2013). CERCLA recognizes that natural and man-made hazardous substance concentrations can occur at a site in excess of natural background concentrations, not as a result of local site-related releases but caused by human activities in areas remote from the site combined with natural processes that transport the contaminants to the site (e.g., atmospheric uptake, transport, and deposition). CERCLA defines “anthropogenic background” as natural and human-made substances present in the environment as a result of human activities, but not related to a specific release from the CERCLA site undergoing investigation and cleanup (USEPA, 2002).

CERCLA generally does not require cleanup to concentrations below anthropogenic background concentrations. In states that have a more stringent state standard, CERCLA cleanups must try to meet state ARARs, or the ARAR must be waived at or before completion of the remedial action. For the Upland OU at Bradford Island, no Oregon soil cleanup values exist that would be identified as either ARARs or TBCs.

As a result, PRGs have been set at regional background concentrations for hazardous substances that have RBTCs below regional background concentrations. The background concentrations selected for use are based on the 95% UCL.

4.3.4 Regional and Site-Specific Background in Soil

This section presents estimates of regional or site-specific background concentrations for those risk driver COCs and CECs with PRGs that are driven by regional background values.

Oregon DEQ has developed both statewide and regional background concentrations for metals (ODEQ, 2013). The applicable region for the Bradford Island Upland OU identified in Oregon DEQ’s 2013 report is the Cascade Mountains physiographic province. These regional background concentrations for the Cascade Mountains are used to represent soil concentrations for chromium and nickel at the Bradford Island Upland OU.

4.3.4.1 Regional Background for Chromium in Soil

The Cascade Mountains regional background 95%UCL is 74.4 mg/kg dw (ODEQ, 2013). Thus, it can be concluded that the presence of chromium in Upland OU site soils is partially driven by the natural occurrence of this analyte at the site.

4.3.4.2 Regional Background for Nickel in Soil

The Cascade Mountains regional background 95%UCL is 49.66 mg/kg dw (ODEQ, 2013). Thus, it can be concluded that the presence of nickel in Upland OU site soils is partially driven by the natural occurrence of this analyte at the site.

4.3.5 Role of Practical Quantitation Limits

CERCLA allows consideration of PQLs when formulating PRGs to address circumstances in which a concentration determined to be protective cannot be reliably detected using state-of-the-art analytical instruments and methods. For example, if an RBTC is below the concentration at which a contaminant can be reliably quantified, then the PRG for that contaminant may default to the analytical PQL. The PQL is defined as the lowest concentration that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using approved methods.

Table 4-3 lists the risk-driver specific PQLs developed for the RI sampling program and documented in the associated quality assurance project plan. These PQLs represent the lowest values that can be reliably quantified when the sample matrix is free of interfering compounds that can reduce sensitivity and raise reporting limits. Also, this table presents the range of actual sample PQLs reported by the laboratories for the data in the RI database. These results reflect the range of what the laboratories were able to achieve given the composition of and matrix complexity associated with site samples.

Analytical quantitation limits are generally not expected to exceed RBTCs or background concentrations for samples of low matrix complexity.

4.3.6 Cumulative Risk

A HI greater than 1 for multiple contaminants, when it did occur, was not directly accounted for when developing PRGs for ecological receptors. Given the high level of uncertainty regarding the mode of action for most contaminants in relation to the ecological receptors, PRGs were instead developed based on each contaminant with a HQ of 1 or greater.

The issue of cumulative risk associated with combined exposure of human and ecological receptors to media of concern within both the River and Upland OUs was not explicitly addressed in development of the PRGs for the Upland OU. Given the different risk drivers for both human and ecological receptors, it is believed cumulative risk is managed to acceptable levels through individual RBTCs calculated separately for the River and Upland OUs.

4.4 Preliminary Remediation Goals

PRGs for soil are derived from a consideration of ARARs, RBTCs, background concentrations, and PQLs. There are no chemical-specific soil ARARs available, and PQLs were not found to influence selection of the PRGs (i.e., all PRGs are above PQLs; Table 4-3). Thus for each AOPC, the PRG for each risk driver is the higher value between the background concentration and the lowest RBTC.

Table 4-4 lists soil PRGs for the risk-driver COCs and CECs. Table 4-4 focuses on both the human health and ecological risk drivers, and is subdivided to address the various spatial applications of the PRGs for the ecological RAO. The PRGs are derived from RBTCs or background values and applied on an average basis over a given exposure area.

For RAO 1, the numerical PRG for Total cPAHs is based on the soil RBTC for the tribal fishing platform scenario.

For RAO 2, PRGs are based on the soil RBTCs (a hazard quotient less than 1) developed for soil exposure by ecological receptors or regional background, whichever is higher.

The RAOs and PRGs are used in Section 6 of the FS to frame development of remedial alternatives. Section 7 compares estimated concentrations of risk drivers to PRGs as one measure of the effectiveness of the remedial alternatives.

While not explicitly addressed in the RAOs for the Upland OU, erosion of the landfill area adjacent to the river needs to be addressed as part of this FS evaluation in order to support overall site remediation, specifically recontamination of the River OU. The need for action to stabilize the slope of the landfill is based on an engineering analysis stating that the landfill slope is unstable and will likely contribute to mass wasting into the River OU (Section 2.2.1.1). Given that elevated concentrations exist in the Landfill AOPC for River OU COCs and CECs identified in the River OU Baseline HHRA and ERA (URS, 2016), it is assumed that not providing slope stability would result in a recontamination of the River OU after any remedial action occurs. This recontamination could potentially result in concentrations above site PRGs for the River OU. Addressing slope stability issues along the landfill will also incidentally support achieving RAOs and PRGs for the Landfill AOPC through removal of contaminated soils. Erosion of the slope encompassed by the Bulb Slope AOPC is also a concern for potential recontamination to the River OU. However, because there is no risk associated with the Bulb Slope AOPC to Upland OU receptors, characterization and potential mitigation of erosion in the Bulb Slope AOPC will be addressed in the River OU FS.

4.5 References

ODEQ. (2013). *Development of Oregon Background Metals Concentrations in Soil, Technical Report.* Oregon Land Quality Division Cleanup Program.

URS. (2012). *Remedial Investigation Report: upland and river operable units. Bradford Island, Cascade Locks, Oregon.*

URS. (2016). Baseline Human Health and Ecological Risk Assessment, River Operable Unit, Bradford Island, Cascade Locks, Oregon.

USEPA. (1988). *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* EPA/540/G-89/004.

USEPA. (1991). *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evalation Manual (Part B, Development of Risk-based Preliminary Remediation Goals).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. EPA 540/R-92/003.

USEPA. (1997). *Rules of Thumb for Superfund Remedy Selection.* Office of Emergency and Remedial Response, Washington, D.C. EPA 540-R-97-013.

USEPA. (1999). *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents, EPA 540-R-98-031.* U.S. Environmental Protection Agency, Washington, D.C.

USEPA. (2002). *Code of Federal Regulations, Title 40—Protection of Environment, Chapter I—EPA, Part 300—National Oil and Hazardous Substances Pollution Contingency Plan.* Sec. 300.5—Definitions (40 CFR 300.5).

5 Identification and Screening of Remedial Technologies

This section describes the identification and screening of technologies consistent with the U.S. Environmental Protection Agency's (EPA) *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988a).

A key early step in the development of remedial alternatives that address Site remedial action objectives (RAOs) is the selection of general response actions (GRAs) that will satisfy the remedial action objectives, and remedial technologies that will be used to develop the alternatives. GRAs describe in very broad terms the types of actions potentially applicable to cleanup of contaminated media. Each GRA may contain one or more technology types. The GRAs evaluated in this FS include performing no action, land use controls, monitoring, monitored natural attenuation (MNA), removal (excavation), in-situ treatment, ex-situ treatment, disposal, and containment. Process options are a further subdivision or tier in the technology screening procedure, and define the specific type of equipment used within a technology.

Remedial technologies and process options that are representative, potentially effective, and implementable were evaluated and certain options were selected to be carried forward for additional consideration in the FS. The screening evaluation was conducted using the effectiveness, implementability, and cost criteria consistent with EPA guidance (EPA 1988a).

- **Effectiveness**. This evaluation focuses on: (1) the potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the remediation goals identified in the remedial action objectives; (2) the potential impacts to human health and the environment during the construction and implementation phase; and (3) how proven and reliable the process is with respect to contaminants and conditions at the site.

- **Implementability**. Implementability encompasses both the technical and administrative feasibility of implementing a technology process. Technical feasibility refers to the ability to construct, operate, maintain, and monitor the action during and after construction. Administrative feasibility refers to the ability to obtain permits for off-site actions (on-site actions would be performed under the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] authorities) and the availability of specific equipment and technical specialists necessary for the action.

- **Cost**. Cost plays a limited role in the screening of process options. At this stage, the cost analysis basis is professional engineering judgment, and each process is evaluated as to whether costs are high, low, or medium relative to other process options in the same technology type.

The complete screening process is summarized in tables as follows:

- Table 5-1 lists all of the candidate remedial technologies and process options evaluated.

- Table 5-2 provides the detailed screening of process options, identifies those retained for further consideration, and includes reasons for eliminating a technology from further consideration.

- Table 5-3 summarizes the technologies and process options evaluated. Those retained after this evaluation were carried forward into the alternatives development process, as representative technologies and process options, and are indicated in the table with gray shading.

The selections consider information from past and current remediation projects elsewhere in the region and nationally where appropriate. Detailed descriptions of the technology types and process options used for cost estimating purposes under each remedial alternative follow. In Section 6, these are assembled into unique or combined alternatives for further evaluation.

5.1 Review and Selection of Representative Process Options

5.1.1 Monitored Natural Attenuation (MNA)

MNA allows ongoing, naturally occurring processes to contain, destroy, or reduce toxicity or bioavailability of contaminants in various media including soils, while monitoring to determine the changes in toxicity. Natural processes that are fundamental to the attenuation of contaminated soils include contaminant transformation, reduction in mobility/bioavailability, physical isolation, and dispersion. An MNA technology would rely upon these processes to reduce unacceptable ecological and human health risks to acceptable levels, while monitoring attenuation over time to verify remedy success. High concentration organics and metals may persist in contaminated surface soils for decades. The primary factors in determining how quickly natural attenuation would occur are likely to be biodegradation and irreversible sorption (Ouvrard et al. 2013). However, sorbed contaminants are not removed from soils, and still may be ingested/contacted by potential receptors.

5.1.1.1 MNA Technology Summary

Due to the persistence of site COCs in shallow soils, MNA, alone or in combination with other technologies, will likely result in unreasonable cleanup times. Therefore, MNA is not retained for further evaluation in this FS.

5.1.2 Removal Technologies

Removal is a common and frequently implemented general response action for soil remediation nationwide.

5.1.2.1 Excavation

Excavation prevents human contact with soils through physical removal of soils for disposal, sometimes preceded by treatment. Excavation generally refers to the removal of soil in the absence of overlying water. Complete removal involves the excavation of all soils with contaminant concentrations above the cleanup levels. Dewatering may be considered if the excavation depth is below the water table and include the use of dewatering pumps. Partial removal may involve the removal of only some of the shallower contaminated soils, followed by other remedial actions to prevent exposure or transport of the deeper contaminated soils (e.g., capping, land use controls). A site-specific element for considering excavation is the structure of the AOPCs. For example, depth to bedrock in the Landfill AOPC and steep slopes found on the island may be important considerations for a removal action. Furthermore, backfill may be required in some or all areas where removal actions are implemented to maintain soil stability and site safety (see Appendix 2 for additional discussion of slope stability concerns in the Landfill AOPC).

5.1.2.2 Soil Vapor Extraction

Soil vapor extraction (SVE) is an in situ unsaturated zone soil remediation technology in which a vacuum is applied to the soil to induce the controlled flow of air and remove volatile and some semi-volatile contaminants from soil (Van Deuren et al 2002). SVE will not remove heavy oils or metals. However, because the process involves the continuous flow of air through the soil, it may promote the in-situ biodegradation of low volatility organic compounds that may be present.

SVE involves drilling one or more extraction wells into contaminated soil to a depth above the water table, but generally deeper than 3 feet below ground surface (USEPA 2012). A blower or vacuum pump is attached to each well to create a vacuum, and the vacuum pulls air and vapors through the soil and up the well to the ground surface for on-site ex-situ treatment (typically via adsorption onto activated carbon or destruction by thermal oxidation). Sometimes, the ground must be paved or covered with a geomembrane or tarp to ensure that the vacuum does not pull air from above ground surface into the system; pulling in clean air reduces the efficiency of the system. The cover also prevents any vapors from escaping from the ground to the air above.

5.1.2.3 Removal Technologies Summary

Excavation is commonly used to address soil contamination. Both complete and partial excavation options are retained in this FS. SVE is not retained because there were no volatile COCs identified in the Upland soils more than 3 feet below ground surface.

5.1.3 Treatment Technologies

Treatment can be defined as any process, manufactured or naturally occurring, which causes the destruction or reduction in toxicity, mobility, or volume of contamination in a given media. Treatment technologies include ex-situ and in-situ options.

Ex-situ treatment is a component of a soil remediation process train that requires soil removal before treatment occurs, followed by disposal or beneficial use of the treated materials. Ex-situ treatment options with potential applicability to the site are physical immobilization by soil washing, chemical extraction, solidification/stabilization, or thermal treatment, or techniques.

In general, in- situ treatment technologies do not require soil removal, and are based on methods that have been successfully implemented as full-scale ex-situ technologies (e.g., stabilization, thermal treatment, etc.). However, because excavation is not required, in-situ treatment techniques are generally less energy-intensive, less expensive, and less disruptive to the environment than ex-situ treatment technologies. In-situ treatment options with potential applicability to the Site are solidification/stabilization, thermal treatment, and phytoremediation.

5.1.3.1 Soil Washing

Conventional soil washing is an ex-situ process that uses readily-available material handling unit processes to separate soil particles, typically into coarse (sand and gravel) and fine (silt and clay) fractions. Advanced soil washing combines the physical separation aspects of conventional soil washing with additional treatment, such as the addition of surfactants or oxidants to the fine fraction of the material. Soil washing is a wet process that generates wastewater requiring treatment and discharge. The washed coarse soil fraction may be suitable for beneficial use, such as material feedstock for other industrial or manufacturing applications (e.g., concrete or asphalt manufacture). The finer fraction, which typically has higher concentrations of contaminants, is typically dewatered, transported, and disposed of in a permitted upland landfill. The ideal outcome of soil washing is a reusable coarse fraction and a reduced volume of contaminated material requiring additional treatment or disposal (USEPA 1988b).

If the soil washing location is on-site, all substantive requirements that are ARARs would be complied with, and all procedural and environmental review requirements would be waived. If the soil washing location is off-site, all necessary permits would need to be obtained. Permits would also be required for any off-site disposal of treated waste streams, such as placement of treated material as off-site fill or off-site discharge of wastewaters to a sanitary sewer.

5.1.3.2 Chemical Extraction

Chemical extraction is an ex-situ process that does not destroy wastes, but is a means of separating hazardous contaminants from soils, thereby reducing the volume of hazardous waste that must be disposed of or treated (Van Deuren et al. 2002). The technology uses an extracting chemical and differs from soil washing, which generally uses water or water with wash-improving additives. Physical separation steps are often used before chemical extraction to grade the soil into coarse and fine fractions, based on the standard assumption that fines contain most of the contamination. Physical separation can also enhance the kinetics of extraction by separating out particulate heavy metals if present in the soil. Chemical extraction is further subdivided into acid extraction and solvent extraction.

Acid extraction, as the name suggests, uses acid to extract heavy metal contaminants from soils. Soils are first screened to remove coarse solids. Acid is then introduced to the soil in the extraction unit. The soil-acid mixture is continuously pumped out of the extraction unit, and the soil and extractant are separated using hydrocyclones. When extraction is complete, the solids are transferred to a water rinse system to remove entrained acid and metals. The extraction solution and rinse waters are then regenerated using commercially available precipitants, along with a flocculant that removes the metals and reforms the acid. The heavy metals are concentrated in a form potentially suitable for recovery. During the final step, the soils are dewatered and mixed with lime to neutralize any residual acid.

Solvent extraction uses chemical solvents under controlled pressure and temperature conditions to separate contaminants, typically organics, from soil (USEPA 1994; USEPA 1998). The solvent extraction process consists of four basic steps: extraction, separation, desorption, and solvent recovery (USEPA 1994). The extraction step involves mixing the soil with solvent. The solids are then separated either by filtration or gravity settling. Separated solids retain some solvent that must be removed by thermal desorption. Contaminant-laden solvent and solvent vapors removed during desorption are transferred to a distillation system. Condensed solvents are normally recycled to the extractor. The bottoms product contains high boiling point contaminants and is recovered for future treatment or disposed of as hazardous waste.

5.1.3.3 Solidification/Stabilization

Solidification involves mechanical blending of contaminated soil, either in-situ or ex-situ, with a solidifying agent such as cement or cement kiln dust. For an in-situ application, the solidifying agent is added in place by injection of a slurry mixture into the soil with auger mixing. The resulting monolith reduces contaminant leachability and inhibits human contact by encapsulating soils. Contaminants are not destroyed by solidification, so excavated solidified soils would still require transport to a landfill for disposal. Depending on the types of contaminants and their concentrations in soils, ex-situ solidification may be required prior to disposal (e.g., TSCA-regulated materials should they be encountered during remediation).

Stabilization refers to processes that involve chemical reactions that reduce the leachability of a waste. Stabilization chemically immobilizes hazardous materials or reduces their solubility. The desired changes for stabilization include converting contaminants into a less soluble, mobile, or toxic form (Wilk 2007). One example is phosphate stabilization. The formation of metal phosphates (e.g., lead phosphates) occurs naturally in the presences of sufficient concentrations of the metal and phosphate. Metal phosphates are typically highly stable minerals that have low solubilities. Phosphate stabilization does not remove metals from the soil, though. Phosphate stabilization is routinely used to treat metals in soil for disposal purposes.

Treatment reagents often both solidify and stabilize the contaminant matrix; hence, this treatment technology is frequently referred to as a solidification/stabilization process. For example, a treatment reagent such as cement can reduce the mobility of many metal contaminants by forming insoluble hydroxides, carbonates, and silicates with them (stabilization), as well as providing a solid encapsulation matrix to reduce leaching (solidification) (Wilk 2007). Also, in some solidifcation/stabilization applications, a stabilization reagent such as phosphate (for some metals) or organoclay (for some organics) can be used to enhance the ability of the binder to encapsulate the contaminants. Cementitious based solidification/stabilization techniques have been demonstrated for most contaminant groups (i.e., semivolatiles, PCBs, pesticides, and metals), but are not expected to be effective for volatiles (Barnett et al 2009). The presence of landfill debris may hinder or prevent in-situ applications due to the inability to auger in solidification/stabilization agents.

5.1.3.4 Thermal Treatment

Thermal treatment involves the ex-situ or in-situ elevation of the temperature of soil to levels that either volatilize the organic contaminants (to be collected and combusted later) or directly combust the contaminants. Thermal treatment does not destroy or volatilize non-volatile metals.

A number of different ex-situ system configurations and operating principles have been developed and are available in the marketplace (e.g., high temperature thermal desorption, incineration, etc.). Thermal treatment systems are generally effective for destroying a broad range of organic compounds. Thermal treatment facilities are not available either locally or regionally. Therefore, excavated soils would need to be transported out of state (to either Idaho or Utah) to utilize an existing facility. Alternatively, a temporary on-site facility is technically feasible to consider but may not be cost-effective. Implementability considerations include general siting considerations. Thermal destruction processes also require monitoring and management of air releases of hazardous constituents, such as dioxins/furans and metals. Dioxins/furans and metals can be created and released in air emissions from some thermal treatment processes.

Many different methods (e.g., electrical resistance heating and thermal conduction heating) and combinations of techniques can be used to apply heat to polluted soil and/or groundwater in-situ. The heat can destroy or volatilize organic chemicals. As the chemicals change into gases, their mobility increases and the gases are extracted via collection wells for capture and cleanup in an ex-situ treatment unit. The main advantage of in-situ thermal methods is that they allow soil to be treated without being excavated and transported, resulting in significant cost savings (Van Deuren et al. 2002); however, in-situ treatment generally requires longer time periods than ex-situ treatment, and there is less certainty about the uniformity of treatment because of the variability in soil and aquifer characteristics and because the efficacy of the process is more difficult to verify.

5.1.3.5 Phytoremediation

Phytoremediation encompasses three mechanisms: rhizodegradation (where exuded phytochemicals can enhance microbial biodegradation of contaminants in the rhizosphere), phytodegradation (ability of plants to take up and break down contaminants in the transpiration stream through internal enzymatic activity and photosynthetic oxidation/reduction), and phytovolatilization (ability of plants to take up, translocate, and subsequently transpire volatile contaminants in the transpiration stream) (ITRC 2009). Phytoremediation may also include phytoextraction (ability of plants to take up contaminants into the plant with the transpiration stream) as long as harvesting and contaminant removal is included in the application. The specific phytoremediation mechanism(s) depends on contaminant properties such as mobility, solubility, and bioavailability.

The typical range of effectiveness for phytoremediation groundcovers is 1 to 2 feet below ground surface (bgs), but depths down to 5 feet have been reported within the range of influence (Olsen and Fletcher 1999). Phytoremediation groundcovers have been applied at various bench- to full-scale remediation projects, including applications to soils impacted with PAHs, and metals (ITRC 2009, USEPA 2010). Low molecular weight PAHs have been remediated using native grasses, perennial ryegrass, introduced cool- and warm-season grasses, and legumes (USEPA 2001). High molecular weight PAHs exist at high concentrations on the site; these are less bioavailable and not successfully remediated by phytotechnologies (Van Epps 2006). Willow and birch trees take up chromium, but it stays in the roots; tumbleweed and Russian thistle accumulate chromium (Pulford et al. 2001; Krishnani et al. 2004; Gardea-Torresdey et al. 2005). Plants in the mustard family accumulate nickel (Chaney et al. 2007). The use of soil amendments and planted systems to stabilize lead in soil is quite effective (USEPA 2007). However, amendments and stabilization would likely not reduce the lead concentrations to meet PRGs for ecological exposure; that is, receptors would still have access to soil with lead concentrations above the PRGs. Significant research has gone into the use of soil chelators to enhance bioavailability of lead (Schnoor 1997), but these amendments can cause the indiscriminate increase of lead mobility and leaching of the chelated lead into surface and groundwater, while not being very effective for increasing lead uptake by plants (Chaney et al. 2007). In summary, phytoremediation could be considered for shallow areas of contamination (<2 feet bgs) where only nickel and/or chromium are the primary CECs.

Phytoremediation may require substantial maintenance efforts. Appropriate care (e.g., watering, fertilizing, applying enhancing agents or herbicides/pesticides, etc.) would need to be taken to ensure successful establishment and continued survival of installed vegetation. Furthermore, installed vegetation may need to be fenced or otherwise protected to prevent humans and/or wildlife from ingesting plants that have accumulated concentrations of contaminants that pose unacceptable risks when ingested. Periodic vegetation harvesting is another method to minimize these types of risks. The necessity for vegetation protection or harvesting is largely dictated by the contaminant of concern and whether it accumulates in the plant tissue to unacceptable levels.

5.1.3.6 Treatment Technologies Summary

Solidification/stabilization is retained as a viable ex-situ treatment technology for this site. Ex-situ soil washing, chemical extraction, and thermal treatment are not believed to be required nor cost-effective for the anticipated amounts of materials to be removed at the site. For locations that involve a relatively small quantity of soil removal, these technologies (soil washing, chemical extraction, thermal treatment) may not be cost effective when compared to disposal. Furthermore, the variety of contaminants present (i.e., inorganics, and PAHs) may require the use of several different types of process options. If identified as part of the preferred alternative, a cost-benefit evaluation would occur during remedial design.

In-situ thermal treatment or solidification/stabilization may be appropriate for AOPCs with substantial amounts of contaminated soil that is more than a few feet below ground surface. Otherwise, surface soils may be more readily accessed and cleaned up via excavation and treatment/disposal or phytoremediation. However, it may be possible to stabilize characteristically hazardous materials in situ within the area of contamination to avoid triggering land disposal restrictions and the need to treat underlying contaminants of concern. Thermal treatment is only applicable to organic COCs. However, there are very few locations where unacceptable levels of organic contaminants do not co-occur with unacceptable levels of metals contamination. Therefore, thermal treatment is not considered further for developing alternatives. In-situ stabilization is not appropriate for use in areas where there may be buried debris. The debris may hinder or prevent in-situ applications due to the inability to auger in solidification/stabilization agents. The primary location where contamination is present greater than 3 feet bgs is the Landfill AOPC, particularly near the Gully Test Pit, where there is likely buried debris in the landfill. Furthermore, in situ stabilization/solidification may hinder or prevent the establishment of some vegetation, and it is preferable to avoid long-term impacts to vegetation. Therefore, in-situ thermal and in-situ stabilization/solidification are not retained for further evaluation in the FS.

Phytoremediation may be successful where only nickel and/or chromium are the primary COCs. This condition, though, only exists in very small portions of the Sandblast Area AOPC. Because there are no unacceptable risks for likely exposure pathways in the Sandblast Area, phytoremediation is not retained for further evaluation in the FS.

5.1.4 Disposal/Reuse Technologies

Disposal is the final component of a soil remediation process train that starts with removal and ends with placement (disposal) in a facility where potential environmental impacts are monitored, controlled, and limited. This process train can also include ex-situ treatment between removal and disposal. Disposal can either be within an on-site disposal facility specifically engineered for the disposal of contaminated soils or within an off-site operating commercial disposal facility. Beneficial reuse is often preferred to disposal, where feasible, although application can be limited by physical characteristics or contaminant concentrations.

5.1.4.1 On-site Disposal

A soil repository could be constructed on an existing area within the site. The repository, which would be covered or revegetated, would allow for disposal of soils in a controlled environment, minimizing exposure due to direct contact with contaminated soil and transport of contaminants through contact with water. The primary limitation for this technology is land availability.

Additionally, if a discrete on-site repository is constructed, the facility would require long-term operation and maintenance (O&M) and additional land use controls.

5.1.4.2 Off-site Disposal

A regional landfill compliant with Resource Conservation and Recovery Act (RCRA) Subtitle C (Waste Management, Inc. located in Arlington, Oregon) is available to receive material with contamination that exceeds relevant RCRA or TSCA limits should such material be encountered during remediation. Two regional Subtitle D-compliant landfills are also available (Waste Management, Inc. in Columbia Ridge, Oregon and Republic Services in Roosevelt, Washington) are also available to receive non-hazardous waste. These existing Subtitle C and D landfills are retained as representative disposal process options for remedial alternatives that call for soil removal with disposal in a landfill.

5.1.4.3 Beneficial Use of Soil (Clean and Treated)

Beneficial use of soil generated from the Site would be preferred to its disposal, where feasible. For contaminated soils removed as part of a cleanup action, treatment would be required before possible beneficial use. Any potential beneficial use application would need to meet associated material specifications to ensure an appropriate match between physical, chemical, and biological material properties and functionality in the desired environment.

Treatment by soil washing or chemical extraction followed by beneficial use may be more cost-effective than treatment followed by disposal. The coarser product (processed material that meets target levels established for the project) from a soil washing or chemical extraction process could potentially be reused for capping, habitat restoration, or grade restoration elsewhere in the region. The sand produced from a soil washing or chemical extraction process could also be reused as construction fill or as material feedstock for other industrial or manufacturing applications (e.g., concrete or asphalt manufacture). Depending on the end use and associated exposure potential, it is unknown whether the treated sand fraction would achieve appropriate chemical criteria for all contaminants. Beneficial use would also require resolution of legal issues related to material classification, antidegradation, and potential liability.

Capping material (soil, sand, gravel, rock, etc.) may be purchased from upland sources, and this is the basis in later chapters for cost estimation purposes. However, the design process should consider the use of materials generated or available as a result of nearby projects determined suitable for beneficial use application as an alternative to purchased materials. Significant administrative issues (including timing, contracting, and administrative approvals) are associated with procuring beneficial use materials.

5.1.4.4 Disposal/Reuse Technologies Summary

Off-site disposal is retained in this FS. On-site disposal is not retained because on-site space limitations may make repository construction impractical. The amount of material to be excavated and the concentrations are important considerations during design. For locations that involve a relatively small quantity of removal, some disposal process options (e.g., beneficial reuse) may not be cost-effective compared to off-site disposal; this evaluation could occur during remedial design. Beneficial use is not retained due to the many issues associated with treatment of, verification monitoring, and administrative approval for reuse of contaminated soils.

5.1.5 Containment Technologies

Capping refers to the placement of clean material over contaminated soils. Capping is a well-developed and documented in-situ remedial technology for soils. Caps may be designed to reduce potentially unacceptable risk through physical isolation of the contaminated soils to reduce exposure by direct contact or prevent leaching to groundwater from contaminated soils above the water table. For the Upland OU, the purpose of a cap would be to physically isolate contaminated soils; leaching to groundwater is not a relevant exposure pathway. Isolation caps may be constructed using uncontaminated soil, geosynthethic barriers, vegetation, or hard, impermeable materials (e.g., concrete, asphalt), but can have more complex designs. Caps may be designed with different layers to serve multiple primary functions or in some cases a single layer may serve multiple functions.

The ability to implement capping technology is influenced greatly by physical constraints and engineering design. Capping may be suitable in areas where it is impractical to remove all of the contaminated material because of stability concerns. If capping is chosen as part of the selected remedial alternative, slope stability and potential future land use would be considered. An engineered cap design specifies material types, gradation, thickness, design elevation ranges, placement requirements, and other design parameters.

5.1.5.1 Soil Capping

Soil caps are constructed using either simple topsoil covers or low permeability clay layers to prevent human contact and transport of soils off site. Simple topsoil caps could be used directly to cover contaminated soil with a protective layer, preventing human contact with the covered contamination. The advantage of topsoil capping is that contaminated soils remain in place, eliminating excavation, transport, and disposal problems. However, in-place capping alone (i.e., without any prior removal) could raise the ground surface level substantially (6 to 12 inches or more). Special precautions might be necessary to prevent erosion or other disturbances that could cause loss of capping material. Soil capping could be used effectively in combination with excavation to achieve proper final grading. Low-permeability clay caps may be used as final cover for soil disposal areas. These types of soil covers are typically used for preventing infiltration of water into a contaminated soil disposal pile to eliminate future contaminant migration from the pile.

5.1.5.2 Geosynthetic Barrier

Geosynthetics can consist of geotextile fabrics and geomembrane barriers. Geotextile fabrics are woven from synthetic material and made to withstand both chemical degradation and biodegradation. The fabric is laid over untreated or undisturbed soils, effectively separating them from clean fill material. Geomembrane barriers also have applicability as cover material over a soil disposal pile to prevent surface water infiltration and control surface migration of contaminants. These types of covers, however, are more costly than soil covers. These kinds of barriers can also serve as a warning of the presence of contaminated soils beneath the fabric.

5.1.5.3 Vegetative Covers

Vegetative covers are composite soil covers with vegetation serving to reduce runoff velocities and inhibit erosion. Vegetative covers can prevent human contact with soils by creating a physical barrier. Roots from cover plants hold the soil in place, preventing erosion and off-site transport by surface runoff or wind. Vegetative covers alone may be appropriate for soils with low contaminant concentrations. Vegetative covers may also be used in conjunction with clay caps, clean fill, or geotextile fabrics. With proper maintenance, they can be an effective barrier. The limitation of a vegetative cover is that routine maintenance may be necessary to maintain the cover. Without proper maintenance, the vegetative cover can die and contaminated soil can be readily re-exposed. Furthermore, vegetative covers alone are only effective if there are land use controls prohibiting digging (e.g., for installation of fishing platforms).

5.1.5.4 Hard Cap

Hard caps can prevent human contact by creating an impermeable physical barrier. A hard cap may include concrete or asphalt. However, these types of products are not appropriate for use in habitat areas, though it may be possible to re-create habitat areas on top of a hard cap if required as mitigation for loss of habitat.

5.1.5.5 Containment Technologies Summary

Application of all capping materials discussed above is retained as part of this FS. The effect of slopes and erosion on cap stability would be AOPC-specific, and will need to be considered during remedial design. In general, though, erosion issues that compound O&M requirements will be present for caps without vegetation.

5.2 Land Use Controls

Land use controls are engineered and non-engineered instruments that help to minimize the potential for exposure to contamination and/or protect the integrity of a response action. Institutional controls (ICs), a subset of land use controls, refer to the non-engineering measures intended to affect human activities in such a way as to prevent or reduce exposure to contaminated material, often by limiting land or resource use. The National Contingency Plan (NCP) sets forth environmentally beneficial preferences for permanent solutions, complete elimination rather than control of risks, and treatment of principal threats to the extent practicable. Where permanent and/or complete elimination are not practicable, the NCP creates the expectation that institutional controls will be used to supplement engineering controls as appropriate for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants. It states that it is EPA's expectation that land use controls will not be used as a sole remedy unless active measures are determined not to be practicable, based on balancing trade-offs among alternatives (40 CFR 300.430 [a][1][iii]).

EPA recommends that where it may provide greater protection, multiple land use controls should be used in combination; this is referred to as "layering." Land use controls may be an important part of the overall cleanup at a site whenever contamination is anticipated to remain, after active remediation, at concentrations that exceed cleanup levels. Land use controls may be applied during remedy implementation to minimize the potential for human exposure (as temporary land use or exposure limitations). These controls may also extend beyond the end of construction (or be created at that time) or even after cleanup levels are achieved to ensure the long-term protectiveness of remedial actions that leave contaminants on site at concentrations that are above cleanup levels (these may be long-term or permanent limitations, such as protecting a contaminant barrier like a cap from being accidentally breached).

Land use controls potentially applicable to cleanup of the Upland OU are identified and discussed below. This section describes specific individual controls in sufficient detail to allow for a comparison of remedial alternatives that include various types and degrees of reliance on institutional controls.

In addition to engineering and physical barriers (such as fences and security guards), EPA guidance broadly lists four types of institutional controls: governmental controls, proprietary controls, enforcement tools, and informational devices. Governmental controls such as the permitting of some discharges to Columbia River (from point sources only, not non-point sources), as well as some enforcement controls (such as consent decrees or administrative orders under which settling parties implement remedies including institutional controls), are not discussed at any depth in this FS because they do not inform the choices among alternative remedies. Governmental controls would, for remedy selection purposes, be uniform across all alternatives and options and therefore need no discussion in comparing between alternatives.

The most important land use controls for the development of remedial alternatives are:

- Physical access restrictions
- Proprietary controls
- Informational devices including public outreach and education

5.2.1 Physical Access Restrictions

Physical access restrictions are tangible measures that can be taken or constructed to directly prevent access to areas where contamination may be present, thereby preventing or limiting exposure. These restrictions may include fencing, or other access prevention measures.

5.2.2 Proprietary Controls

Proprietary controls are recorded rights or restrictions placed in property deeds or other documents transferring property interests that restrict or affect the use of property. Covenants are a grant or transfer of contractual rights. Easements are a grant of property rights by an owner, often for a specific purpose (e.g., access, utility, environmental, and other types of easements). Covenants and easements are essentially legally binding arrangements that allow or restrict usage of property for one or more specific objectives (e.g., habitat protection, protection of human health, etc.). They commonly survive the transfer of properties through real estate transactions and are binding on successors in interest who have not participated in their negotiation. This distinguishes covenants and easements from ordinary contracts or transactions between or among parties. At cleanup sites, covenants and easements commonly control or prevent current and future owners from conducting or allowing activity that could result in the release or exposure of buried or capped contamination as long as necessary. However, deed restrictions are not a valid institutional control for government property, as the property cannot be encumbered. A similar institutional control would have USACE put a requirement in the installation plan. Potential activities controlled or prohibited by the update to the installation plan may include construction activities where buried contamination may become exposed as a result of the activity, as long as it is an activity the owner may legally control. A complex balancing of interests by USACE, ODEQ, and other stakeholders would be involved in selecting a less expensive remedy in the form of a proprietary control that limits future property uses in ways a more expensive remedy would not. For example, a proprietary control can lower remedial costs for a former owner at the expense of the redevelopment options of a current owner, who acquired the property after it was contaminated. For this reason, among others, EPA policy and guidance stress assessing reasonably anticipated future land use as an important part of remedy selection generally, and specifically stress limiting use of land use controls.

5.2.3 Informational Devices

5.2.3.1 Public Outreach and Education

An enhanced approach called community-based social marketing was adopted at the Palos Verdes Superfund site in California (EPA 2009a, 2009b). This approach, pioneered by Doug McKenzie-Mohr of St. Thomas University in Canada in 1999, as cited in EPA (2009a), includes:

- Researching to establish and quantify baseline behaviors and size/demography of different populations and to identify culturally-specific barriers and benefits.
- Defining desired behaviors and understanding barriers to achieving those behaviors; defining incentives for overcoming barriers and achieving behavior change.
- Creating effective messages/incentives and effective delivery and monitoring mechanisms.
- Implementing culturally-appropriate outreach to all target populations using brief, clear, tested messages and incentives.
- Following up on research after a time period to monitor and evaluate levels of behavior change and to modify the approach as needed.

A collaborative advisory group could be convened to develop a site-specific framework and technical approach. Likely participants would include USACE, ODEQ, other interested federal, state, and local government agencies, and the Native American Tribes. A key mandate of the advisory group would be the founding of a small, credible, and knowledgeable core team to facilitate the effort. The overall goal of this effort would be to develop and implement a public outreach and education program that focuses on incentives and activities that research indicates have the greatest likelihood of adoption and would make the greatest substantive difference in environmental health. Implementation of the outreach and education program could be accomplished in a number or ways, stressing culturally-appropriate teams, objective and credible participants, and a systematic approach to applying, documenting, and quantifying results of this approach. The advisory group would recommend program elements based on ideas generated by the group and the affected communities, and a review of approaches demonstrated to have caused positive behavior changes at other sites. It would also recommend appropriate programmatic changes as needed based on the evolution of monitoring and survey-based information.

Example elements of an outreach and education program for increasing awareness of site risks include:

- Increase the use of signs containing information regarding site use.
- Conduct outreach efforts at camping and fishing locations on a regular basis.

- Disseminate site-related information at community health facilities, schools, and at community based functions.
- Encourage medical and other health professionals to communicate risks to the public.

A significant difference between the Palos Verde site and the Bradford Island site is the presence in the Columbia River of tribal fishing access rights secured by treaties of the United States and the potential for future use of the Island by the tribes for fishing and camping. Nothing in this section or anywhere in this FS is intended to suggest that exercise of such rights, or the underlying cultural traditions, would be precluded by any public outreach or education efforts. For this reason, the public outreach and education programs should be developed in consultation with affected Tribes to develop accommodations for such Tribes to the greatest extent practicable.

5.2.4 Land use Controls Summary

Some of the land use controls described in this section are inherently difficult to enforce. Future use of the island includes long-term tribal access. It is anticipated that some people may choose to contact contaminated soils regardless of public outreach and education programs, and it is not the intent of this FS to restrict access to areas of the Island that have been secured by treaties. For these reasons, land use controls will be relied on only to the extent necessary to develop practicable remedial actions for the Bradford Island Upland OU.

5.3 Monitoring

Monitoring is an important tool for collecting data to be used assessment and evaluation, and is a requirement of remedial action conducted under CERCLA. Monitoring data are collected and used to assess the completeness of remedy implementation, remedy effectiveness, and the need for contingency actions.

Typically, sampling and testing process options are prescribed components of project monitoring plans, which, in turn, focus on different aspects of the remedial action. For example, monitoring during the construction phase has different objectives than the operation and maintenance (O&M) monitoring that follows construction. Five different monitoring concepts that form the basis for individual or combined monitoring plans, depending on project-specific circumstances, are described below.

5.3.1 Baseline Monitoring

Baseline monitoring establishes a statistical basis for comparing physical and chemical site conditions prior to, during, and after completion of a cleanup action. Baseline monitoring for the Bradford Island Upland OU may entail the sampling and analysis of soil samples during Remedial Design in accordance with a sampling design that enables such a statistical comparison of conditions.

5.3.2 Construction Monitoring

Construction monitoring during active remediation is area-specific and short-term, and is used to evaluate whether the project is being constructed in accordance with plans and specifications (i.e., performance of contractor, equipment, and environmental controls). This type of monitoring evaluates water quality in the vicinity of the construction operations to determine whether contaminants are adequately controlled.

5.3.3 Post-construction Performance Monitoring

Post-construction performance monitoring at the conclusion of construction evaluates post-remediation soil conditions. Both chemical and physical data may be collected to determine whether the work complies with project specifications.

5.3.4 Operation and Maintenance (O&M) Monitoring

O&M monitoring refers to data collection for the purpose of tracking the technology performance, long-term effectiveness, and stability of individual soil cleanup areas. In capping areas, O&M monitoring typically consists of analysis that includes determining COC and CEC concentrations and cap thickness.

5.3.5 Long-term Monitoring

Long-term monitoring evaluates soil at the site for an extended period following the remedial action to assess risk reduction and progress toward achievement of cleanup levels. Data collected under long-term monitoring yields information reflecting the combined actions of soil remediation and source control.

5.3.6 Monitoring Summary

Monitoring is an essential element of remedial alternatives developed in this FS. Monitoring will take place prior to, during, and after completion of a cleanup action and will include baseline, construction, post-construction, O&M, and long-term monitoring as applicable to the actions included in the remedial alternatives.

5.4 Ancillary Technologies

5.4.1 Best Management Practices (BMPs)

The specific array of BMPs or engineering controls implemented during cleanup will be location-specific and will be determined during design of the remedial alternative. Often, the remedial design specifications define certain BMPs along with performance requirements (such as erosion control measures) to which the contractor must adhere. The contractor typically is required to provide additional details on specific BMPs in their work plans. Monitoring and adaptive management are common practices that will be used to refine and optimize BMPs throughout the duration of the project to ensure compliance with the project performance requirements. Some representative BMPs have been identified as part of the FS remedial alternatives to develop cost estimates.

5.5 Summary of Representative Process Options for the FS

The representative process options carried forward to Section 6 for potential development and evaluation of remedial options are shown in Table 5-3.

5.6 References

Barnett, F., S. Lynn, and D. Reisman 2009. *Technology Performance Review: Selecting and Using Solidification/Stabilization Treatment for Site Remediation*. EPA/600/R-09/148. November 2009.

Chaney, R.L., Angle. J.S., Broadhurst, C.L., Peters, C.A., Tappero, R.V., and Sparks, D.L. 2007. "Improved Understanding of Hyperaccumulation Yields Commercial Phytoextraction and Phytomining Technologies." Journal of Environmental Quality. Vol 36, p 1429-1443.

Gardea-Torresdey, J.L., de la Rosa, G., Peralta-Videa, J.R., Montes, M., Cruz-Jimenez, G., and Cano-Aguilera, I. 2005. "Differential uptake and transport of trivalent and hexavalent chromium by tumbleweed (Salsola kali)."Archives of Environmental Contamination and Toxicology. Vol 48, p 225-232.

Krishnani, K., Parimala, V., and Meng, X.G. 2004. "Detoxification of chromium(VI) in coastal water using lignocellulosic agricultural waste." Water SA. Vol 30, p 541-545.

ITRC (Interstate Technology and Regulatory Council) 2009. *Phytotechnology Technical and Regulatory Guidance and Decision Trees, Revised*. PHYTO-3. Washington, D.C.: Interstate Technology and Regulatory Council, Phytotechnologies Team, Tech Reg Update.

Olsen, P.E. and J.S. Fletcher 1999. Field evaluation of mulberry root structure with regard to phytoremediation. *Bioremediation* 3, 27-33.

Ouvrard, S., E.D. Chenot, J.F. Masfaraud, and C. Schwartz 2013. Long-term assessment of natural attenuation: statistical approach on soils with aged PAH contamination. *Biodegradation* 24, 539-548.

Pulford, I.D., Watson, C., and McGregor, S.D. 2001. "Uptake of chromium by trees: prospects for phytoremediation." Environmental Geochemistry and Health. Vol 23, p 307-311.

Schnoor, J.L. 1997. *Phytoremediation*. Ground-Water Remediation Technologies Analysis Center Technology Evaluation Report TE-98-01.

USEPA (U.S. Environmental Protection Agency) 1988a. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*. EPA/540/G-89/004. U.S. Environmental Protection Agency, Washington, D.C. 1988.

USEPA 1988b. *Technology Screening Guide for Treatment of CERCLA Soils and Sludges*. EPA/540/2-88/004. U.S. Environmental Protection Agency, September 1988.

USEPA 1994. *Solvent Extraction Engineering Bulletin*. EPA/540/S-94/503. U.S. Environmental Protection Agency, April 1994.

USEPA 1998. *Remediation Case Studies: Ex-situ Soil Treatment Technologies (Bioremediation, Solvent Extraction, Thermal Desorption)*. EPA/542/R-98-011. U.S. Environmental Protection Agency, September 1998.

USEPA 2001. *Phytoremediation of Contaminated Soil and Ground Water at Hazardous Waste Sites*. EPA/540/S-01/500. U.S. Environmental Protection Agency, February 2001.

USEPA 2007. *The Use of Soil Amendments for Remediation, Revitalization and Reuse*. EPA/542/R-07/013. U.S. Environmental Protection Agency, December 2007.

USEPA 2009a. *Draft Palos Verdes Shelf Superfund Site Institutional Controls Program Implementation Plan*. Prepared by U.S. Environmental Protection Agency Region 9, January 2009.

USEPA 2009b. *Palos Verdes Shelf Superfund Site, Operable Unit 5 of the Montrose Chemical Corp. Superfund Site Final Feasibility Study.* Prepared by U.S. Environmental Protection Agency Region 9, May 2009.

USEPA. 2010. *Phytotechnologies for Site Cleanup*. EPA/542/F-10/009. U.S. Environmental Protection Agency, September 2010.

USEPA 2012. *A Citizen's Guide to Soil Vapor Extraction and Air Sparging*. EPA 542/F-12-018. U.S. Environmental Protection Agency, September 2012.

Van Deuren, J., T. Lloyd, S. Chhetry, R. Liou, and J. Peck 2002. *Remediation Technologies Screening Matrix and Reference Guide*, 4th Edition. Prepared by Platinum International, Inc. for the U.S. Army Environmental Center. January 2002.

Van Epps, A 2006. *Phytoremediation of Petroleum Hydrocarbons*. Prepared for EPA Office of Solid Waste and Emergency Response. August 2006.

Wilk, C. 2007. *Principles and use of solidification/stabilization treatment for organic hazardous constituents in soil, sediment, and waste*. Waste Management '07 Conference, 25 February – 1 March 2007, Tucson, Arizona.

6 Development of Remedial Alternatives

This section presents the rationale, assembly, and description of remedial alternatives for cleanup of the Bradford Island Upland OU. These alternatives are assembled in a manner consistent with CERCLA guidance (USEPA 1988).

The development of remedial alternatives is a culmination of the analyses and findings in the previous sections of the FS including regulatory requirements, RAOs, and PRGs as defined in Section 4 and representative remedial technologies retained following screening in Section 5.

One No Action alternative and other more active remedial alternatives were developed for each AOPC. In total, five remedial alternatives have been developed for the Landfill AOPC, and three for the Pistol Range AOPC. No remedial alternatives were formulated for the Sandblast Area and Bulb Slope AOPCs, as no unacceptable risk was found in the baseline human health and ecological risk assessments (Section 3) for this area.

6.1 Framework and Assumptions for Making Technology Assignments

This section describes the criteria and assumptions used to guide the assignment of remedial technologies for the remedial alternatives. A two-step process was used for assigning technologies to the remedial alternatives. First, the spatial extent of remediation is developed for each AOPC. Second, remedial technologies are assigned using a set of defined technology criteria assumptions based on the predicted effectiveness of the remedial technologies under site conditions.

6.1.1 Spatial Extent of Remediation

This section describes the development of remedial footprints established for some alternatives. AOPC-wide average concentrations for a COC or CEC risk driver that exceed a PRG at the corresponding soil depth trigger the need for remediation. When the 95% UCL concentrations for the identified COCs or CECs are below the PRGs for the corresponding depth interval within an individual AOPC, acceptable levels of risk will be achieved. Generally, alternatives other than the no action alternatives were developed to achieve the PRG for all COC or CEC risk drivers. Alternative L2 is an exception, and was developed based on anticipated future actions at the site; 95% UCLs for this alternative was still calculated in order to compare to other alternatives. Other COCs and CECs identified in the baseline human health and ecological risk assessments (Section 3), but not identified as risk drivers, will also be addressed through the remedial alternatives. An evaluation of the impacts of the remedial alternatives on other COCs and CECs is provided in Section 7.

Landfill AOPC

Based on the RAOs and PRGs, a soil depth interval of 0 – 3 feet below ground surface (bgs) is considered for fishing platform user exposures and ecological exposure when developing the remedial footprint. The remedial footprint is informed by the PRGs as follows:

- cPAHs – 0.073 mg/kg
- Chromium – 74.4 mg/kg
- Copper – 78 mg/kg

- Lead – 54 mg/kg
- Mercury – 0.19 mg/kg
- Nickel – 49.66 mg/kg
- Total HPAHs – 5.92 mg/kg

Pistol Range AOPC

Based on the RAOs and PRGs, only a soil depth interval of 0 – 3 feet bgs for ecological exposure needs to be considered when developing the remedial footprint. The only CEC that poses an unacceptable risk is lead, for which the PRG is 78 mg/kg.

6.1.2 Hot Spot Analysis

The 1995 amendments to ORS 465.315 and the 1997 amendments to OAR 340-122, commonly referred to as the Environmental Cleanup Rules, require that certain actions be taken for "hot spots" of contamination (ODEQ, 1998). These actions are a) the identification of hot spots as part of the RI and FS and b) the treatment of hot spots, to the extent feasible, as part of a remedial action.

Assessing a site for hot spots in soil first requires an evaluation of the baseline risk. If the baseline risk exceeds the acceptable risk, it is necessary to determine if any areas of contamination at the site constitute hot spots of contamination resulting from contamination that is "highly concentrated," "highly mobile", or "not reliably containable." As discussed previously, the risk assessment showed contaminant concentrations in soil above acceptable risk levels for particular exposure pathways in the Landfill and Pistol Range AOPCs. Thus, those AOPCs should be evaluated to identify if there are any hot spots present. No unacceptable risk was identified in the Bulb Slope AOPC due to the limited occurrence of mercury exceedances for ecological receptors and no unacceptable risk for human health receptors. Additionally, no unacceptable risk was identified in the Sandblast AOPC because human health risk fell within EPA's acceptable risk range and because ecological risk was determined to not have significant community or population level impacts and because the Sandblast AOPC is expected to be maintained for industrial use, thus not providing suitable wildlife habitat warranting remedial action. Given the determination that no unacceptable risk was identified for the Bulb Slope and Sandblast AOPCs, further examination of these areas as part of the Hot Spot analysis is not warranted.

"Highly Concentrated"

The assessment of "highly concentrated" soil hot spots is performed by comparing the concentration of each individual site contaminant to its "highly concentrated" hot spot level. The "highly concentrated" hot spot levels are "risk-based concentrations" corresponding to a given multiplier of the acceptable risk level. These levels are:

- 100 times the acceptable risk level for human exposure to each individual carcinogen;
- 10 times the acceptable risk level for human exposure to each individual non-carcinogen;

- For Threatened and Endangered Species, 10 times the acceptable risk level for individual ecological receptors or populations of ecological receptors to each individual hazardous substance; and
- For non- Threatened and Endangered Species, 50 times the acceptable risk level for individual ecological receptors or populations of ecological receptors to each individual hazardous substance

Highly Mobile

Mobility refers to the transport or migration of hazardous substances from their present location. Typical routes of migration include infiltration or leaching through subsurface soils into groundwater and stormwater runoff into surface waters.

Not Reliably Containable

As described in the Environmental Cleanup Rules, the feasibility study should determine the extent to which hazardous substances cannot be reliably contained for identifying "not reliably containable" hot spots. This assessment should be performed during the evaluation of long-term effectiveness and permanence, which is one of the balancing criteria for evaluating remedial alternatives. Factors to be considered when evaluating the reliability of containment include whether contaminated soils are in direct contact with groundwater or surface water; located in areas prone to floods, landslides, or vandalism; prone to leaching to groundwater; and prone to surface runoff. In most cases, contamination that is "not reliably containable" will likely result in either "highly mobile" or "highly concentrated" hot spots. Thus, this criterion seldom affects the outcome of the hot spot determination.

Hot Spot Identification

For the Pistol Range AOPC, only ecological risk was identified at unacceptable levels. Because there are no Threatened and Endangered Species present at Bradford Island, a multiplier of 50 was applied to the acceptable risk level for lead. No locations within the Pistol Range AOPC were identified as being "highly concentrated" hot spots.

For the Landfill AOPC, both ecological and human health risk were identified at unacceptable levels. Similar to the Pistol Range AOPC, a multiplier of 50 was applied to the acceptable risk levels for CECs. Multipliers of 100 (for carcinogenic risk) and 10 (for non-carcinogenic risk) were applied to acceptable risk levels for COCs. Seventeen unique "highly concentrated" hot spots were identified because of exceedances of these threshold levels (Table 6-1). There are no "highly mobile" or "not reliably containable" hot spots.

6.1.3 Other Considerations Not Addressed in Technology Assignments

This section addresses some additional considerations that need to be evaluated during remedial design, but were not used to assign remedial technologies in the FS. These include utilities and slope stability.

6.1.3.1 Utilities

Utilities are important site features to understand and factor into remedial alternatives. Location-specific evaluations will be needed regarding whether material can be placed over buried utilities or setback distances that may be required when excavating near utilities. The presence of buried utilities is a consideration for implementation but is not assumed to prevent the use of remedial technologies. Relocation of utilities was not included as a line item in the cost estimate.

6.1.3.2 Slope Stability

A slope stability analysis was performed for the north island bluff adjacent to the Landfill AOPC (USACE 2015; also Appendix 2). The analysis concluded that the north bank slope adjacent to the Landfill AOPC is experiencing recession as a result of wave erosion. This wave erosion causes the bank to become oversteepened, resulting in periodic erosion, soil creep, and shallow landsliding. Future mass wasting should be anticipated, including shallow landslides that fail to depths of 3 to 10 feet. Future failures will likely mobilize landfill material adjacent to the bank and along the bank, causing fill material to enter the river. Slope stability analyses confirm that the north bluff slope is near its natural angle of repose and has a low factor of safety.

Because of the steep and high nature of the bank and the potential for mobilization of landfill material into the river, slope stabilization measures are recommended. Stripping back the landfill would likely be the most cost-effective slope stabilization measure. It is recommended that the landfill material be stripped back from the existing upper bluff edge a minimum of 12 to 20 feet, depending on the factor of safety desired. However, because the base of the bluff will likely continue to erode in the future as a result of wave activity, a greater setback may be warranted. Based on the observation that the base of the bluff has eroded approximately 15 feet since dam construction (from 1935 to 2010), the average annual recession rate would be 2.4 inches per year. If the same rate occurs in the future, the base of the bluff could recede an additional 10 feet in the next 50 years. Therefore, the landfill setback would need to be increased to 22 to 30 feet to maintain the desired minimum factor of safety (Figure 6-1). Other alternatives laid out in the slope stability analysis, such as buttressing the slope or using an anchored shotcrete wall, have significant cost, regulatory, and/or implementability issues.

Except for the No Action alternative, alternatives for the Landfill AOPC include the landfill setback in order to minimize mobilization of landfill material into the river. While setback of the landfill does not directly address any of the RAOs (Section 4) for the Upland OU, it is considered pertinent to ensure transfer of contaminants to the River OU from the Landfill AOPC is eliminated. As such, this action is incorporated into development of remedial alternatives for the Landfill AOPC. The landfill setback is assumed to be 30 feet in order to achieve a factor of safety of 1.5 (orange line in Figure 6-1). Landfill materials north of the orange line are to be fully excavated and not backfilled; however, this area will be reseeded with native vegetation. For this FS, it is assumed that COC and CEC concentrations in soils beneath landfill materials are equivalent to the reference area concentrations, but further investigation during remedial design may be warranted and is assumed. Landfill materials south of the orange line are expected to be graded to the south at a 2H:1V slope until the existing grade is met, and vegetation will be reestablished upon the completion of regrading. For this FS, it is assumed that this slope will need to extend for 15 feet to meet the existing grade; this is conservative based on the results presented in the slope stability analysis.

Other than the north island bluff adjacent to the Landfill AOPC, this FS does not attempt a design-level analysis of the potential for slope failure. During remedial design, engineering evaluations of bearing capacity and slope stability may be performed as necessary.

6.2 Common Elements for all Remedial Alternatives

6.2.1 Common Engineering Assumptions

This section discusses the physical and logistical constraints related to implementation of all remedial alternatives and the engineering assumptions made to address them in the FS.

6.2.1.1 Site Preparation and Staging

Site preparation is location-specific, and is generally limited to clearing the remediation areas of vegetation, debris, and other obstructions as needed. Site preparation is assumed to consist mostly of clearing and grubbing, though some other activities may be necessary depending on the technology chosen and the specific location within an AOPC.

Staging refers to upland operational areas that support material and equipment handling. For planning purposes, this FS assumes that suitable land is available on Bradford Island for staging and support activities, though specific staging areas have not been identified.

6.2.2 Technology-Specific Engineering Limitations and Assumptions

6.2.2.1 Removal, Backfill, and Disposal

Removal is assumed to consist of excavation with a backhoe or excavator. Vegetation will be removed prior to excavation. Assumed excavation depth is a function of exposure pathways (e.g., assumed fishing platform user exposure depths are 0 to 3 feet bgs), the depth of contamination, and the scope of the alternative. Generally, as stated in Section 6.1.1, the 95% UCL of the top 3 feet of material must be lower than the PRG for each COC and CEC risk driver. In practice, excavation of deeper soils will also include excavation of the overlying soils; that is, excavation of contaminated soils from a 2 to 3 feet bgs interval will also include excavation of potentially less contaminated soils from a 0 to 2 feet bgs interval.

Backfill will be utilized in all excavation areas and slopes will be graded to the pre-excavation grade except where necessary to pull back slopes to address potential future slope failures. Clean backfill material will be obtained from a nearby location. For the purpose of developing conservative excavation and backfill or capping footprints, the following assumptions regarding the concentrations of risk drivers in the backfill were made:

- The organic COC and CEC risk driver concentrations of the backfill material are assumed to be equivalent to the average of the reference area
- The metal CEC risk driver concentrations of the backfill material are assumed equivalent to the means of the Cascade Range region dataset (ODEQ, 2013).

The assumed COC and CEC risk driver concentrations in backfill material are shown in Table 6-2. Backfill material will be tested for contamination prior to delivery to assure that it is clean. Reseeding of native vegetation will occur following backfilling of the excavation.

For the purposes of this FS, it is assumed that all excavated materials will be disposed of and that none would be reused as backfill elsewhere. The toxicity characteristic leaching procedure (TCLP) is typically used to determine if a waste constitutes a characteristic waste, which must be disposed of in a subtitle C landfill. TCLP is an extraction method for chemical analysis employed as an analytical method to simulate leaching through a landfill. The extract, a liquid, is analyzed for substances appropriate to the protocol. TCLP extraction results are typically given in units of milligrams per liter. However, the TCLP does allow for a total constituent analysis in lieu of the TCLP extraction. If a waste is 100% solid, then the results of the total constituent analysis may be divided by 20 to convert the total results into the maximum leachable concentration (http://www3.epa.gov/epawaste/hazard/testmethods/faq/faq_tclp.htm). The value obtained can be used to show whether or not the maximum theoretical concentration in a leachate from a waste could not exceed the toxicity characteristic value. Because TCLP data are not available for the Upland OU, this estimation method will be performed to determine if excavated soils can be taken to a subtitle D or must be taken to a subtitle C landfill. TCLP maximum values and maximum leachable concentrations for chemicals of interest in the Uplands are shown in Table 6-3. If a soil concentration is greater than the maximum leachable concentration, then it is assumed that the material must be disposed of in a subtitle C landfill. Arsenic has not been detected above its maximum leachable concentration. Lead in soils frequently exceeds the maximum leachable concentration in the Landfill and Pistol Range AOPCs (see e.g., Figures 3-1 through 3-3). Chromium also frequently exceeds the maximum leachable concentration in the Landfill AOPC, and is almost always accompanied by a lead exceedence (see e.g., Figures 3-1 and 3-2). Mercury and chlordane exceed their maximum leachable concentrations only in one sample each in the Landfill AOPC, but these samples are accompanied by a lead exceedence. Because lead and chromium above their respective maximum leachable concentrations are so widespread, it is likely that most excavated material would be disposed of in a subtitle C landfill (e.g., Waste Management, Inc. in Arlington, Oregon). However, it is assumed that composite samples will be taken to characterize the excavated material prior to disposal.

6.2.2.2 Capping

Capping is assumed to consist of either placement of an adequate thickness of material (same assumed composition as backfill material) without prior excavation or installation of a hard cap (for example, asphalt) appropriate for vehicle traffic. Areas that do not currently or are reasonably not expected to experience vehicle traffic are not recommended for paving. There are no areas where paving is considered the preferred capping technology; none of the areas in the Landfill and Pistol Range AOPCs are used for equipment storage and/or already endure some amount of vehicle traffic. The preferred capping methodology in these areas are clearing and grubbing, followed by placement of an adequately thick layer of capping material and reseeding with native vegetation.

For penetrable caps (i.e., caps that are not hard caps), assumed cap thickness is a function of exposure pathways (e.g., assumed fishing platform user exposure depths are 0 to 3 feet bgs) and the depth of contamination. Generally, as stated Section 6.1.1, the 95% UCL of the top 3 feet of material must be lower than the PRG for each COC or CEC risk driver.

6.2.2.3 Land Use Controls

The major types of land use controls considered for this FS are: 1) physical access restrictions, 2) proprietary controls, and 3) informational devices. These are discussed in more detail in Section 5.2.

Land use controls apply to remedial alternatives where deemed necessary. Physical access restrictions are assumed to be necessary during remedy construction, but the current access restrictions are assumed to be adequate. Long-term physical access restrictions are assumed necessary for alternatives that do not satisfy RAO 1. Proprietary controls are assumed to be necessary where potential future activities may result in the exposure of buried contamination or the establishment of a new post-remedy exposure point concentration as a result of the activity; this would include all alternatives where contamination above the PRG(s) is left in place. Potential activities controlled or prohibited may include construction activities where buried contamination may become exposed as a result of the activity, as long as it is an activity the owner may legally control. Informational devices in the form of public outreach and education are expected to be implemented as part of most remedial alternatives to inform potential site users of the remaining risks associated with the site. Additionally, a geotextile warning barrier between shallow excavations/backfill and caps and deeper contamination that is left in place is considered. The vivid color and warning text on this kind of geotextile warns of potential danger at the point of any future excavations.

6.2.3 Remedial Design Investigations and Evaluation

Remedial design investigations include location-specific sampling or testing for the purpose of refining the design and engineering assumptions for the selected remedy. Upland OU-wide data collection and analyses that have been performed are useful for understanding overall site characteristics and making FS-level cleanup decisions, but additional sample collection may be needed for remedial design. These investigations are primarily intended to refine the remedial footprint and/or excavation depth. Cost and scope for remedial design sampling and design preparation are incorporated into remedial alternatives costs.

6.2.4 Monitoring

Monitoring is a key assessment technology for soils remediation that satisfies the need to verify achievement of project RAOs. For contaminated soils projects involving capping and/or excavation, monitoring likely consists of the following components:

- **Construction monitoring** – location-specific short-term monitoring during construction to ensure performance of the operations
- **Post-construction performance monitoring** – location-specific performance monitoring immediately following completion of active remediation
- **O&M Monitoring** – area- and location-specific monitoring to confirm that technologies are operating as intended

Construction and post-construction monitoring are common to all alternatives. Construction monitoring confirms that human health and the environment are adequately protected during construction. Post-construction monitoring confirms that remedial actions have achieved cleanup standards or other performance standards. O&M monitoring is necessary for capping alternatives to ensure the integrity of the cap. O&M monitoring may consist of visual inspections, surveys, and through-cap cores.

6.2.5 Project Sequencing

Project sequencing refers to the order in which AOPCs or the site as a whole are remediated. Sequencing is an important consideration from a recontamination perspective. The timing of individual Upland OU AOPC remedial actions is not expected to affect actions in other Upland OU AOPCs. However, it is preferred to first address portions of the Landfill AOPC where there is evidence of an unstable slope (see Section 6.1.2.2). Failure of the slope could result in landfill material eroding into the River OU, which is to be avoided.

6.3 Detailed Description of Remedial Alternatives

6.3.1 Landfill AOPC Alternatives

This section describes the remedial alternatives for the Landfill AOPC. There are five alternatives proposed for the Landfill AOPC. Other than Alternatives L1 and L2, alternatives are designed to achieve both RAO1 and RAO2. The 95% UCLs remaining following remediation in the Landfill AOPC are provided for each alternative in Table 6-4.

6.3.1.1 Alternative L1 – No Action

Alternative L1 is the no action alternative for the Landfill AOPC. Alternative L1 includes no remedial actions, monitoring, or land use controls. The present value of the cost for Alternative L1 is assumed to be $0.

6.3.1.2 Alternative L2 – Landfill Cutback and Land Use Controls

Alternative L2 addresses the area of the landfill that is recommended to be cut back. As discussed previously, the entire depth of landfill material will be removed to the orange line in Figure 6-2, and that the COC or CEC risk driver concentrations remaining in the cutback area are equal to the Reference Area. Behind the cutback, soil would be graded at a 2H:1V slope until the existing grade is met; this is approximately 15 feet behind the cutback. COC and CEC risk driver concentrations in the sloped area (between the orange and yellow lines in Figure 6-2) are assumed to be adequately represented by the samples in the area, excluding surface sample BIL06SSI; BIL06 was taken at depth at the same location and is likely more representative due to the slope regrading. Where a COC or CEC risk driver does not have data for BIL06, BIL06SSI was assumed to be representative (cPAHs and Total HPAHs). In total, approximately 1,988 cubic yards (53,676 cubic feet) of material are estimated to be removed. The cutback area will be reseeded with native vegetation.

Additional sampling is not necessary prior to excavation, but a pre-construction survey would be completed.

In addition to typical construction BMPs, measures should be considered to prevent transport of upland soils to the River OU. These measures may include temporary installation of decking or other means to intercept loose soil prior to entering the river. These measures are expected to increase the complexity of the construction; thus, a higher level of complexity is assumed for estimating the costs associated with this alternative and other landfill alternatives (L3 through L5) that include the landfill cutback than for alternatives that address other AOPCs.

Construction monitoring and post-construction monitoring (i.e., a post construction survey) would occur for this alternative. O&M monitoring for this alternative is limited to periodic land use control inspections.

There are no known current or future plans for construction in the Landfill AOPC, but because contamination is left in place above acceptable levels, land use controls are necessary. Proprietary controls are considered necessary to restrict actions that would expose buried contamination or significantly alter the exposure point concentrations. Access restrictions are considered necessary because unacceptable risks remain for potential human receptors. Current restrictions (i.e., industrial facility behind fencing, guards present) limit human exposures, but potential future restrictions could include a security fence around the landfill. Potential future tribal users may not be subject to proprietary controls; therefore, informational devices (perhaps including informational signage) are necessary for this alternative.

The estimated present value of the cost of Alternative L2 is $661,199.

6.3.1.3 Alternative L3 – Landfill Cutback, Additional Shallow Excavation and Backfill, Land Use Controls

Alternative L3 includes the landfill cutback in Alternative L2 and additional shallow excavation (0-3 feet bgs) and backfill to further reduce exposure point concentrations. The cPAH PRG is the primary factor in the development of the remedial footprint.

Based on achievement of both RAOs, the additional excavation and backfill footprint for Alternative L3 is approximately 9,937 square feet (Figure 6-3). This additional excavation and backfill includes the sloped area (shown in black in Figure 6-3) and excavation in three other areas (shown in red in Figure 6-3). Excavation and backfill would include clearing and grubbing, excavating the top 3 feet of soil, covering the excavated area with a geotextile warning layer, backfilling, and reseeding and establishing the backfilled area with native vegetation. The volume of contaminated soil removed is approximately 3,092 cubic yards (83,487 cubic feet), while the volume of loose backfill material is approximately 1,435 loose cubic yards (LCY).

Prior to excavation, additional samples would be taken to further delineate the excavation footprint, and a pre-construction survey would be completed.

Construction monitoring and post-construction monitoring (i.e., a post construction survey) would occur for this alternative. O&M monitoring is for this alternative is limited to periodic land use control inspections.

There are no known current or future plans for construction in the Landfill AOPC, but because contamination is left in place above acceptable levels, land use controls are necessary. Proprietary controls are considered necessary to restrict actions that would expose buried contamination or significantly alter the exposure point concentrations. Access restrictions are not considered necessary because there are no remaining unacceptable risks. Even though there are no unacceptable risks to human receptors, human actions may significantly alter the exposure point concentrations of COCs and/or CECs in the Landfill AOPC. Potential future tribal users may not be subject to proprietary controls; therefore, informational devices (perhaps including informational signage) are necessary for this alternative.

The estimated present value of the cost of Alternative L3 is $976,080.

6.3.1.4 Alternative L4 – Landfill Cutback, Capping and Land Use Controls

Alternative L4 includes the landfill cutback in Alternative L2, additional excavation and backfill in the sloped area, and capping in other areas to further reduce exposure point concentrations. This additional excavation and backfill includes the sloped area (shown in black in Figure 6-3) and capping in three other areas (shown in red in Figure 6-3). The additional excavation and backfill is proposed in the sloped area in order to maintain the elevations and slope recommended for the cutback; this footprint is approximately 1,675 square feet. The capping footprint is approximately

8,262 square feet. Capping would include clearing and grubbing, covering the to-be capped area with a geotextile warning layer, capping with 3 feet of imported clean material, and reseeding and covering the capped area with vegetation. The volume of imported clean material is approximately 1,626 LCY.

Prior to capping, additional samples would be taken to further delineate the capping footprint, and a survey would be completed.

Construction monitoring and post-construction monitoring would occur for this alternative. O&M monitoring would be necessary for this alternative, and would consist of visual cap and land use control inspections, repairs, vegetation maintenance, and reporting on an annual basis.

There are no known current or future plans for construction in the Landfill AOPC, but because contamination is left in place above acceptable levels, land use controls are necessary. Proprietary controls are considered necessary to restrict actions that would expose buried contamination or significantly alter the exposure point concentrations. Access restrictions are not considered necessary because there are no remaining unacceptable risks. Even though there are no unacceptable risks to human receptors, human actions may significantly alter the exposure point concentrations COCs and/or CECs in the Landfill AOPC. Potential future tribal users may not be subject to proprietary controls; therefore, informational devices (perhaps including informational signage) are necessary for this alternative.

The estimated present value of the cost of Alternative L4 is $882,654.

6.3.1.5 Alternative L5 – Landfill Cutback, Complete Landfill Excavation and Backfill

Alternative L5 includes the landfill cutback in Alternative L2 and additional excavation (assumed to be 0 - 10 feet bgs) and backfill to remove all of the landfill material (Figure 6-4). The deep excavation is proposed due to concerns that future human actions could alter the exposure point concentrations of COCs or CECs to levels that are not protective. The additional excavation and backfill footprint for Alternative L5 is approximately 21,565 square feet. Excavation and backfill would include clearing and grubbing, excavating the top 10 feet of soil remaining after the cutback, backfilling, and reseeding and establishing the backfilled area with native vegetation. The volume of contaminated soil removed is approximately 10,841 cubic yards (292,707 cubic feet), while the volume of loose backfill material is approximately 10,357 LCY; however, these volumes could change depending on the results of remedial design sampling.

Prior to excavation, additional samples would be taken to further delineate the excavation footprint, both laterally and vertically, and a survey would be completed.

Construction monitoring and post-construction monitoring would to occur for this alternative. O&M monitoring is not necessary for this alternative.

Contamination above acceptable levels, if still remaining on site, is not expected to be exposed regardless of future actions at the site. Therefore, land use controls are not necessary.

The estimated present value of the cost of Alternative L5 is $2,432,840.

6.3.2 Pistol Range AOPC Alternatives

This section describes the remedial alternatives for the Pistol Range AOPC alternatives. There are three alternatives proposed for the Pistol Range AOPC. Other than Alternative PR1, the no action alternative, alternatives are designed to achieve RAO2. The Pistol Range AOPC does not have any unacceptable exposure risks to humans; therefore, RAO1 does not apply. The 95% UCLs remaining following remediation in the Pistol Range AOPC are provided for each alternative in Table 6-5.

6.3.2.1 Alternative PR1 – No Action

Alternative PR1 is the no action alternative for the Pistol Range AOPC. Alternative PR1 includes no remedial actions, monitoring, or land use controls. The present value of the cost for Alternative PR1 is assumed to be $0.

6.3.2.2 Alternative PR2 – Shallow Excavation and Backfill

Alternative PR2 addresses the remedial footprint (approximately 840 square feet; Figure 6-5) by clearing and grubbing, excavating the top 3 feet of soil, backfilling with imported clean material, and reseeding and establishing the backfilled area with native vegetation. The volume of contaminated soil removed is approximately 93 cubic yards (2,520 cubic feet), while the volume of loose backfill material is approximately 121 LCY.

Prior to excavation, additional samples would be taken to further delineate the excavation footprint.

Construction monitoring and post-construction monitoring would occur for this alternative. O&M monitoring is not necessary for this alternative.

There are no known current or future plans for construction in the Pistol Range AOPC. Contamination is not expected deeper than shallow soils because of the known use of the AOPC as a shooting range, and lead is not generally not very mobile in soils. Thus, soils beneath 3 feet are assumed to meet the lead PRG. Significant alteration of the exposure point concentration for lead would be difficult due to the below- and near-PRG concentrations remaining following excavation and backfill. That is, only a small portion of the remaining surface soils (0 to 3 feet bgs) after excavation will contain lead concentrations above the PRG. Re-grading or mixing such soils with other soils (for whatever future use) in the Pistol Range AOPC post-remedial action is not expected to increase the exposure point concentration to an unacceptable level. Therefore, future users are not expected to significantly alter the exposure point concentration of lead in the Pistol Range AOPC, and proprietary controls are not considered necessary. Access restrictions are not considered necessary because there are no remaining unacceptable risks. Furthermore, because there are no unacceptable risks to human receptors and no known or reasonably expected future activities (post-remedial action) are likely to significantly alter the exposure point concentration of lead in the Pistol Range AOPC, informational devices are not necessary.

The estimated present value of the cost of Alternative PR2 is $76,131.

6.3.2.3 Alternative PR3 – Capping and Land Use Controls

Alternative PR3 addresses the remedial footprint (approximately 840 square feet; Figure 6-5) by clearing and grubbing, covering the to-be capped area with a geotextile warning layer, capping with 3 feet of imported clean material, and reseeding and establishing the capped area with native vegetation. The volume of imported clean material is approximately 101 LCY.

Prior to capping, additional samples would be taken to further delineate the capping footprint, and that a survey would be completed.

Construction monitoring and post-construction monitoring would occur for this alternative. O&M monitoring would be necessary for this alternative, and would consist of visual cap and land use control inspections, repairs, and reporting on an annual basis.

There are no known current or future plans for construction in the Pistol Range AOPC, but because contamination is left in place above acceptable levels, land use controls are necessary. Proprietary controls are considered necessary to restrict actions that would expose buried contamination or significantly alter the exposure point concentrations for lead. Access restrictions are not considered necessary because the only unacceptable risks are for ecological receptors; ecological receptors (e.g., the American Robin) are not substantially impeded by access controls such as fencing and signage. Even though there are no unacceptable risks to human receptors, human actions may significantly alter the exposure point concentration of lead in the Pistol Range AOPC. Potential future tribal users may not be subject to proprietary controls; therefore, informational devices (perhaps including informational signage) are necessary for this alternative.

The estimated present value of the cost of Alternative PR3 is $123,307.

6.3.3 Cost Estimates

Tables 6-6 and 6-7 present best-estimate present value costs for the remedial alternatives. These costs were developed in accordance with USEPA guidance (USEPA 2000) and are presented in great detail in Appendix 3. It is important to acknowledge uncertainty in the accuracy of these cost estimates. The level of detail employed in making these estimates are conceptual but are considered appropriate for differentiating between alternatives. The cost estimates are based on the best available information regarding the anticipated scope of the respective remedial alternatives.

Remedial action alternative cost estimates are intended to provide a measure of total costs over time (“life cycle costs”) associated with an alternative. The level of detail is similar in all of the alternatives to avoid comparing estimates having different levels of accuracies. RACERTM (Remedial Action Cost Engineering and Requirements) version 11.2.16.0 cost data base by Earth-Tech, Inc. (2015) was used for cost estimates.

Several factors can influence the accuracy of estimated remedial alternative costs at the FS level. In particular the costs are very sensitive to the estimated excavation removal volumes. Modest changes in the estimated excavation removal volume can significantly impact costs. Other factors, such as cost fluctuation in fuel and labor, can also significantly impact costs. The FS cost estimates are best estimates based on present day costs, projected into the future. Future economic conditions are difficult to predict. For this reason, the relative accuracy of the cost estimates is likely better for alternatives with shorter durations than for those with longer durations. Overall, the cost sensitivity values fall close to or within the cost accuracy range of -30 to +50 percent expected by USEPA for FS-level estimates (USEPA 2000).

In accordance with EPA guidance (USEPA 2000), the best-estimate costs are reported in terms of their net present values. Net present value analysis is a standard method used to express expenditures that occur over different time periods on a common basis. A discount rate is applied to represent the difference between the rate of return on investments and the rate of inflation. USEPA (2000) guidance recommends using discount rates published in Appendix C of Office of Management and Budget (OMB) Circular A-94 for federal projects. This FS uses a discount rate of

1.4% based on the 30-year real (i.e., inflation-adjusted) discount rate published in the December 2014 revisions of Appendix C to the OMB Circular (OMB 2015).

6.4 References

ODEQ (State of Oregon Department of Environmental Quality). 1998. Guidance for Identification of Hot Spots. April 1998.

ODEQ (State of Oregon Department of Environmental Quality). 2013. Development of Oregon Background Metals Concentrations in Soil. March 2013.

OMB (Office of Management and Budget). 2015. 2015 Discount Rates for OMB Circular No. A-94. https://www.whitehouse.gov/sites/default/files/omb/memoranda/2015/m-15-05.pdf. January 2015.

USACE (U.S. Army Corps of Engineers). 2015. Memorandum for Record (Slope Stability Analysis). Prepared by USACE, Portland District. October 2015.

USEPA (U.S. Environmental Protection Agency). 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final. EPA/540/G-89/004. October 1988.

USEPA. 2000. A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. EPA 540/R-00/002. July 2000.

7 Analysis of Alternatives

This section presents a detailed analysis of the remedial alternatives using the FS criteria outlined in CERCLA, the NCP, and other relevant guidance. As discussed in Chapter 6, these alternatives cover the range of potential actions considered feasible for the cleanup of the Bradford Island Uplands. A comparative evaluation of the remedial alternatives under CERCLA follows the detailed analysis.

7.1 Overview of Evaluation Criteria

The NCP requires consideration of nine evaluation criteria to address the CERCLA statutory requirements. The first two criteria are categorized as threshold criteria:

- Overall protection of human health and the environment
- Compliance with ARARs

For any alternative, these two criteria must be met to be considered viable as a remedy for cleanup. The next five criteria are balancing criteria:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

These five balancing criteria are weighed within the context of evaluating an alternative as a whole. These five criteria together with the threshold criteria form the basis for the detailed evaluation. The last two criteria are modifying criteria:

- State/Tribal acceptance
- Community Acceptance

These are typically assessed following agency and public comment on the Proposed Plan.

7.1.1 Threshold Criteria

CERLCA prescribes threshold criteria that must be met by a remedial alternative. This section discusses how an alternative meets these criteria. It serves as a summary of how the alternatives achieve the cleanup objectives, and what expected statutory or other relevant requirements must be achieved during implementation of the remedial action.

7.1.1.1 Overall Protection of Human Health and the Environment

This criterion addresses whether a remedial alternative provides adequate protection of human health and the environment. CERCLA guidance (EPA 1988) states the assessment of overall protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. The assessment of overall protection provided for each remedial alternative describes how site risks are eliminated, reduced, or controlled through treatment, land use controls, or combinations of these general response actions.

7.1.1.2 Compliance with ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

The ARARs listed in Chapter 4 are not discussed explicitly as part of evaluating the remedial alternatives. Other than the no action alternatives, the remedial alternatives are assumed to comply with these ARARs because the required engineering design and agency review process will ensure that the selected remedy complies with those ARARs; all the alternatives can be designed and implemented in compliance with these ARARs. Such ARARs may affect remedy implementation, but do not have a substantial effect on the fundamental viability of a remedial alternative. It is expected that all action and location specific ARARs will be complied with.

7.1.2 Balancing Criteria

The following subsections describe the balancing criteria and the metrics used to evaluate each criterion.

7.1.2.1 Long-Term Effectiveness and Permanence

The evaluation of alternatives under this criterion addresses the results of a remedial action in terms of the relative magnitude and type of risks remaining at the site after response objectives have been met. Additionally, the evaluation should assess the adequacy and reliability of the controls used to manage residual risks from contamination remaining at the site after remediation or from treatment residuals.

- <u>Magnitude of residual risks</u> – Assesses the residual risk remaining from untreated waste or treatment residuals at the conclusion of remedial activities. The potential for risk may be measured by numerical standards (such as cancer risk levels) or the volume or concentration of contaminants in waste, media, or treatment residuals remaining on the site. The characteristics of the residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

- <u>Hot Spots</u> - DEQ guidance for conducting Feasibility Studies also recommends inclusion of the Hot Spot Analysis in the evaluation of each alternative. The degree to which each alternative treats hot spots is assessed (summarized in Table 7-1).

- <u>Adequacy and reliability of controls</u> – Assesses the adequacy and suitability of controls, if any, that are used to manage treatment residuals or untreated wastes that remain at the site. It may include an assessment of containment systems and land use controls to determine if they are sufficient to ensure that any exposure to human and environmental receptors is within protective levels. This factor also addresses the long-term reliability of management controls providing continued protection from residuals. It includes the assessment of the potential need to replace components of the alternative, such as a cap or treatment system, and the potential exposure pathway and the risks posed should the remedial action need replacement.

7.1.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment

This evaluation criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances as their principal element. This evaluation focuses on the following specific factors for a remedial alternative:

- The treatment processes the remedy will employ, and the materials they will treat
- The amount of hazardous materials that will be destroyed or treated, including how the principal threat(s) will be addressed
- The degree of expected reduction in toxicity, mobility, or volume
- The degree to which treatment is irreversible
- The type and quantity of treatment residuals that will remain following treatment
- Whether the alternative would satisfy the statutory preference for treatment as a principal element

7.1.2.3 Short-term Effectiveness

The evaluation of short-term effectiveness addresses how an alternative affects human health and the environment during the construction phase of the remedial action and until cleanup objectives are met. The following factors should be addressed as appropriate for each alternative:

- Protection of the community during remedial actions – Addresses any risk that results from implementation of the proposed remedial action, such as dust from excavation or transportation of hazardous materials.
- Protection of workers during remedial actions – Assesses threats that may be posed to workers and the effectiveness and reliability of protective measures that would be taken.
- Environmental impacts – Addresses the potential adverse environmental impacts that may result from the construction and implementation of an alternative and evaluates the reliability of the available mitigation measures in preventing or reducing the potential impacts.
- Time until remedial response objectives are achieved – Estimates the time required to achieve protection for either the entire site or individual elements associated with specific site areas or threats.

7.1.2.4 Implementability

The implementability criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during implementation. This criterion involves analysis of the following factors:

- Technical feasibility
  - Construction and operation – relates to the technical difficulties and unknowns associated with a technology.

- Reliability of technology – focuses on the likelihood that technical problems associated with implementation will lead to schedule delays.
- Ease of undertaking additional remedial action – discusses what, if any, future remedial actions may need to be undertaken and how difficult it would be to implement such additional actions.
- Monitoring considerations – addresses the ability to monitor the effectiveness of the remedy and includes an evaluation of the risks of exposure should monitoring be insufficient to detect a system failure.

- Administrative feasibility – Activities needed to coordinate with other offices and agencies
    - Availability of services and materials
    - Availability of adequate offsite treatment, storage capacity, and disposal services.
    - Availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources.
    - Availability of services and materials, plus the potential for obtaining competitive bids, which may be particularly important for innovative technologies
    - Availability of prospective technologies

7.1.2.5 Cost

The cost criterion evaluates the capital and long-term operation, monitoring, and maintenance (O&M) costs of each remedial alternative. Capital costs consist of direct and indirect costs. Direct costs include expenditures for the equipment, labor, and materials necessary to install remedial actions. Indirect costs include expenditures for engineering, financial, and other services that are not part of the actual installation activities, but are required to complete the installation of the remedial alternatives. O&M costs are post-construction costs necessary to ensure the continued effectiveness of a remedial action, including long-term maintenance, repair and monitoring costs. This criterion also includes costs for land use controls. Consistent with CERCLA guidance, the cost estimates were prepared in the absence of detailed engineering design information and have a target level of accuracy ranging from +50% to -30%.

7.1.3 Modifying Criteria

The final two detailed evaluation criteria are the modifying criteria: state/tribal acceptance and community acceptance. This criterion will be addressed in the Record of Decision (ROD) once comments on the FS and Proposed Plan have been received.

7.1.3.1 State/Tribal Acceptance

This assessment evaluates the technical and administrative issues and concerns the state and tribes may have regarding the alternatives. This criterion will be addressed in the ROD once comments on the FS and Proposed Plan have been received. In the interim, State, Tribal, and other stakeholders will continue to be engaged by the USACE in regular meetings and in other forums.

7.1.3.2 Community Acceptance

This assessment evaluates the issues and concerns the public may have regarding each of the alternatives. As with State/Tribal acceptance, this criterion will be addressed in the ROD once comments on the FS and Proposed Plan have been received.

7.2 Detailed Analysis of Alternatives: Landfill AOPC

7.2.1 Alternative L1 - No Action

Alternative L1 is the No Action Alternative. This alternative is not formulated with specific risk reduction goals in mind. However, it does provide a basis to compare the relative effectiveness of the other alternatives.

7.2.1.1 Overall Protection of Human Health and the Environment

Alternative L1 provides little protection of human health and the environment. Unacceptable site risks remain and this alternative does not include any new land use controls.

7.2.1.2 Compliance with ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

Because this alternative does not meet the threshold criteria it will not be evaluated further.

7.2.2 Alternative L2 - Landfill Cutback and Land Use Controls

Under Alternative L2, the entire ten foot depth of an area previously identified as having stability issues would be cutback. The edge of this area would then be graded at a 2:1 vertical slope to meet existing grade. A total of 1,988 cubic yards of material are estimated to be removed.

7.2.2.1 Overall Protection of Human Health and the Environment

Alternative L2 provides some protection of human health. Site risks are lowered and concentrations of all risk driver COCs and CECs have decreased. However, concentrations are above the preliminary remediation goals (PRGs) for all contaminants.

Human health risks are lowered through a combination of the remedial action and land use controls. Current controls such as access restrictions will remain in place and an additional fence around the landfill will be installed. This alternative also requires proprietary controls to restrict actions that would expose buried contamination or significantly alter the exposure point concentrations. Informational devices will also be installed.

A majority of the PRGs for RAO 2 are not achieved. Ecological receptors are not typically restricted by land use controls such as fencing, so risks for ecological receptors remain.

7.2.2.2 Compliance with ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

Because this alternative does not meet the threshold criteria, it will not be evaluated further.

7.2.3 Alternative L3 - Landfill Cutback, Additional Shallow Excavation and Backfill, Land Use Controls

Under Alternative L3, the entire ten foot depth of an area previously identified as having stability issues would be cutback. The edge of this area would then be graded at a 2:1 vertical slope to meet existing grade. An additional area south of the cutback would also have shallow excavation of three feet below ground surface (bgs) and backfill in that same area would also occur. A total of 3,092 cubic yards of material are estimated to be removed.

7.2.3.1 Overall Protection of Human Health and the Environment

Alternative L3 provides protection of human health and is assumed to meet the first RAO. Concentrations of cPAHs are assumed to meet background.

Site risks to the environment are minimized. This alternative achieves the PRGs for all CECs, meeting RAO 2.

This alternative includes proprietary controls to restrict actions that would expose buried contamination or significantly alter the exposure point concentrations.

7.2.3.2 Compliance with ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

7.2.3.3 Long-term Effectiveness and Permanence

- Magnitude and Type of Residual Risk - Reductions in contaminant concentrations, and thus potential exposures and risk, are estimated at the completion of construction. Proprietary controls are included in the alternative to restrict actions that would expose buried contamination or significantly alter exposure point concentrations. Residual risks would remain for ecological receptors.

  The residual concentrations for each RAO are shown in Table 7-2 and described as follows:

  RAO 1 – The 95% UCL for cPAHs in soil was reduced to 0.062 mg/kg, achieving the PRG.

  RAO 2 - Alternative L3 results in 95% UCLs that meet the PRGs for all CECs.

- Hot Spots - The footprint of Alternative L3 removes all of the 17 unique “highly concentrated” hot spots.

- Adequacy and Reliability of Controls - Soil removal and backfilling are reliable and proven technologies as long as they are designed for the appropriate environmental and anthropogenic conditions. Alternative L3 includes land use controls such as signage to minimize human health risks because contamination above acceptable levels is left in place.

  Reviews at least every five years, as required, would be necessary to evaluate the effectiveness of this alternative because hazardous substances would remain on-site in concentrations above levels that allow for unlimited use and unrestricted exposure.

  O&M and long-term monitoring (after construction and confirmation sampling are completed) such as sign maintenance is anticipated for land use controls.

7.2.3.4 Reductions in Toxicity, Mobility, or Volume through Treatment

This alternative does not include any treatment.

7.2.3.5 Short-term Effectiveness

- Community and Worker Protection - This alternative involves excavation and import of material. Construction is assumed to proceed for approximately four to six months. Construction and operation activities may result in temporary noise, light, odors, potential air quality impacts and disruptions to community and workers.

  Off-site disposal may result in upland impacts to the community through increased vehicular traffic (direct transport to off-site disposal) with potential increases in accidents and air-quality issues associated with dust, odor, and vehicular exhaust.

  Measures to minimize short-term risks to the community will be addressed through implementation of health and safety plans and the use of BMPs. Examples of BMPs include pollution controls to minimize emissions and odors from construction activities and isolating work areas with an adequate buffer zone so that occupational workers avoid the construction area.

- Environmental Impacts - Environmental impacts would result from construction efforts. Such impacts would include ground disturbance for excavation and creation of haul roads, air emissions from construction equipment, and nuisance noise. Best management practices can be utilized to minimize many of these impacts.

- Time to Achieve Cleanup Objectives - Achievement of cleanup objectives is expected to occur at completion of remedy implementation (4-6 months).

7.2.3.6 Implementability

Alternative L3 is administratively and technically feasible. Excavation is a common practice and will not likely present unforeseen technical problems or schedule delays during construction of the alternative. Removed material is assumed to be disposed of at a Subtitle C landfill within approximately 100 miles of the site. Equipment and backfill material are also readily available within a reasonable distance of the site.

7.2.3.7 Cost

Estimated total cost to implement Alternative L3 is $976,080.

7.2.4 Alternative L4 - Landfill Cutback, Capping and Land Use Controls

Under Alternative L4, the entire ten foot depth of an area previously identified as having stability issues would be cutback. The edge of this area would then be graded at a 2:1 vertical slope to meet existing grade. Additional excavation to three feet bgs is proposed in the sloped area in order to maintain the elevations and slope recommended for the cutback; this footprint is approximately 1,675 square feet. The estimated excavation volume is 2,177 cubic yards. Additionally, a three-foot cap would be installed over an 8,262 square-foot area.

7.2.4.1 Overall Protection of Human Health and the Environment

Alternative L4 provides protection of human health and is assumed to meet the first RAO. Concentrations of cPAHs are assumed to meet background.

Alternative L4 also provides protection of the environment. This alternative achieves the PRGs for all CECs, meeting RAO 2.

7.2.4.2 Compliance with ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

7.2.4.3 Long-term Effectiveness and Permanence

- Magnitude and Type of Residual Risk - Reductions in contaminant concentrations, and thus potential exposures and risk, are estimated at the completion of construction. Proprietary controls are included in the alternative to restrict actions that would expose buried contamination or significantly alter exposure point concentrations. Residual risks would remain for ecological receptors

  The residual concentrations for each RAO are shown in Table 7-2 and described as follows:

  RAO 1 – The 95% UCL for cPAHs in soil was reduced to 0.062 mg/kg, achieving the PRG.

  RAO 2 – Alternative L4 results in 95% UCLs that meet the PRGs for all CECs.

- Hot Spots - The footprint of Alternative L4 removes 16 of the 17 unique "highly concentrated" hot spots and caps the remaining one.

- Adequacy and Reliability of Controls - Soil removal and capping are reliable and proven technologies as long as they are designed for the appropriate environmental and anthropogenic conditions. Alternative L4 includes land use controls such as signage to minimize human health risks because contamination above acceptable levels is left in place.

  Reviews at least every five years, as required, would be necessary to evaluate the effectiveness of this alternative because hazardous substances would remain on-site in concentrations above levels that allow for unlimited use and unrestricted exposure.

  Operation and maintenance activities and land use controls will be implemented to assure protectiveness and reliability of the remedial action. In addition to confirmation sampling, O&M Monitoring consisting of visual cap and land use control inspections and reporting is assumed to be necessary. O&M activities such as cap repair will be required if any issues are reported during monitoring. Activities such as sign maintenance are anticipated for the land use controls.

7.2.4.4 Reductions in Toxicity, Mobility, or Volume through Treatment

This alternative does not include any treatment.

7.2.4.5 Short-term Effectiveness

- Community and Worker Protection - This alternative involves excavation and import of material. Construction is assumed to proceed for approximately four to six months. Construction and operation activities may result in temporary noise, light, odors, potential air quality impacts and disruptions to community and workers.

Off-site disposal may result in upland impacts to the community through increased vehicular traffic (direct transport to off-site disposal) with potential increases in accidents and air-quality issues associated with dust, odor, and vehicular exhaust.

Measures to minimize short-term risks to the community will be addressed through implementation of health and safety plans and the use of BMPs. Examples of BMPs include pollution controls to minimize emissions and odors from construction activities and isolating work areas with an adequate buffer zone so that occupational workers avoid the construction area.

- Environmental Impacts - Environmental impacts would result from construction efforts. Such impacts would include ground disturbance for creation of haul roads, air emissions from construction equipment, and nuisance noise. Best management practices can be utilized to minimize many of these impacts.
- Time to Achieve Cleanup Objectives - Achievement of cleanup objectives is expected to occur at completion of remedy implementation (6-8 months).

7.2.4.6 Implementability

Alternative L4 is administratively and technically feasible. Excavation and capping are common practices and will not likely present unforeseen technical problems or schedule delays during construction of the alternative. Removed material is assumed to be disposed of at a Subtitle C landfill within approximately 100 miles of the site. Equipment, backfill, and capping material are also readily available within a reasonable distance of the site.

7.2.4.7 Cost

Estimated total cost to implement Alternative L4 is $882,654.

7.2.5 Alternative L5: Landfill Cutback, Complete Landfill Excavation and Backfill

Under Alternative L5, the entire ten foot depth of an area previously identified as having stability issues would be cutback. The edge of this area would then be graded at a 2:1 vertical slope to meet existing grade. This alternative also includes additional excavation to remove all landfill material. This results in the removal of approximately 10,841 cubic yards of material.

7.2.5.1 Overall Protection of Human Health and the Environment

Alternative L5 provides protection of human health and is assumed to meet the first RAO. Concentrations of cPAH are assumed to meet background.

Alternative L4 also provides protection of the environment. This alternative achieves the PRGs for all CECs, meeting RAO 2.

7.2.5.2 Compliance with ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

7.2.5.3 Long-term Effectiveness and Permanence

- Magnitude and Type of Residual Risk - Reductions in contaminant concentrations, and thus potential exposures and risk, are estimated at the completion of construction. The residual concentrations for each RAO are shown in Table 7-2 and described as follows:

RAO 1 – The 95% UCL for cPAHs in soil was reduced to 0.026 mg/kg, achieving the PRG.

RAO 2 - Alternative L5 results in 95% UCLs that meet the PRGs for all CECs.

- Hot Spots - The footprint of Alternative L5 removes all of the 17 unique "highly concentrated" hot spots.
- Adequacy and Reliability of Controls - Soil removal is a reliable and proven technology as long as it is designed for the appropriate environmental and anthropogenic conditions.

  O&M, long-term monitoring (after completion of construction and confirmation sampling), and land use controls are not necessary for this alternative because any contamination remaining on site is not expected to be exposed.

7.2.5.4 Reductions in Toxicity, Mobility, or Volume through Treatment

This alternative does not include any treatment.

7.2.5.5 Short-term Effectiveness

- Community and Worker Protection - This alternative involves excavation and import of material. Construction is assumed to proceed approximately six to eight months. Construction and operation activities may result in temporary noise, light, odors, potential air quality impacts and disruptions to community and workers.

  Off-site disposal may result in upland impacts to the community through increased vehicular traffic (direct transport to off-site disposal) with potential increases in accidents and air-quality issues associated with dust, odor, and vehicular exhaust.

  Measures to minimize short-term risks to the community will be addressed through implementation of health and safety plans and the use of BMPs. Examples of BMPs include pollution controls to minimize emissions and odors from construction activities and isolating work areas with an adequate buffer zone so that occupational workers avoid the construction area.

- Environmental Impacts - Environmental impacts would result from construction efforts. Such impacts would include ground disturbance for excavation and creation of haul roads, air emissions from construction equipment, and nuisance noise. Best management practices can be utilized to minimize many of these impacts.
- Time to Achieve Cleanup Objectives - Achievement of cleanup objectives is expected to occur at completion of remedy implementation (6-8 months).

7.2.5.6 Implementability

Alternative L5 is administratively and technically feasible. Excavation is a common practice and will not likely present unforeseen technical problems or schedule delays during construction of the alternative. Removed material is assumed to be disposed of at a Subtitle C landfill within approximately 100 miles of the site. Equipment and backfill material are also readily available within a reasonable distance of the site.

7.2.5.7 Cost

Estimated total cost to implement Alternative L5 is $2,432,840.

7.3 Detailed Analysis of Alternatives: Pistol Range AOPC

7.3.1 Alternative PR1 - No Action

Alternative PR1 is the No Action Alternative. This alternative is not formulated with specific risk reduction goals in mind. However, it does provide a basis to compare the relative effectiveness of the other alternatives.

7.3.1.1 Overall Protection of Human Health and the Environment

Alternative PR1 provides little protection of human health and the environment. This alternative does not achieve adequate protection. Lead (a CEC) exceeds its PRG and the maximum concentration of lead remaining exceeds the regional default background concentration. Site risks remain and the alternative does not include any new land use controls.

7.3.1.2 Compliance with ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

Because this alternative does not meet the threshold criteria it will not be evaluated further.

7.3.2 Alternative PR2 - Shallow Excavation and Backfill

Alternative PR2 includes shallow excavation (zero to 3 feet bgs) and backfill. The estimated volume of soil removed is 93 cubic yards.

7.3.2.1 Overall Protection of Human Health and the Environment

Alternative PR2 provides protection of human health and the environment because the alternative achieves the applicable PRG for the CEC risk driver in shallow soil, thus meeting the applicable RAO.

7.3.2.2 Compliance with ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

7.3.2.3 Long-term Effectiveness and Permanence

- Magnitude and Type of Residual Risk - Reductions in contaminant concentrations, and thus potential exposures and risk, are estimated at the completion of construction. The residual concentrations for each RAO are shown in Table 7-3 and described as follows:

  RAO 1 – Not applicable for this AOPC

  RAO 2 - Alternative PR2 results in a 95% UCL of 72 mg/kg for the CEC, achieving the PRG.

  Contamination above acceptable levels, if still on site, is not expected to be exposed because only a small portion of the remaining surface soils will contain lead concentrations above the PRG. Regrading or mixing of the soils for any future use is not expected to increase the exposure point concentrations to an unacceptable level.

- Hot Spots – no "highly concentrated" hot spots were identified in the Pistol Range AOPC.
- Adequacy and Reliability of Controls - Soil removal is a reliable and proven technology as long as it is designed for the appropriate environmental and anthropogenic conditions.

  O&M, long-term monitoring (after completion of construction and confirmation sampling), and land use controls are not necessary for this alternative.

7.3.2.4 Reductions in Toxicity, Mobility, or Volume through Treatment

This alternative does not include any treatment.

7.3.2.5 Short-term Effectiveness

- Community and Worker Protection - This alternative involves excavation and import of material. Construction is assumed to proceed for approximately one month. Construction and operation activities may result in temporary noise, light, odors, potential air quality impacts and disruptions to community and workers.

  Off-site disposal may result in upland impacts to the community through increased vehicular traffic (direct transport to off-site disposal) with potential increases in accidents and air-quality issues associated with dust, odor, and vehicular exhaust.

  Measures to minimize short-term risks to the community will be addressed through implementation of health and safety plans and the use of BMPs. Examples of BMPs include pollution controls to minimize emissions and odors from construction activities and isolating work areas with an adequate buffer zone so that occupational workers avoid the construction area.

- Environmental Impacts - Environmental impacts would result from construction efforts. Such impacts would include ground disturbance for excavation and creation of haul roads, air emissions from construction equipment, and nuisance noise. Best management practices can be utilized to minimize many of these impacts.
- Time to Achieve Cleanup Objectives - Achievement of cleanup objectives is expected to occur at completion of remedy implementation (1 month).

7.3.2.6 Implementability

Alternative PR2 is administratively and technically feasible. Excavation is a common practice and will not likely present unforeseen technical problems or schedule delays during construction of the alternative. Removed material is assumed to be disposed of at a Subtitle C landfill within approximately 100 miles of the site. Equipment and backfill material are also readily available within a reasonable distance of the site.

7.3.2.7 Cost

Estimated total cost to implement Alternative PR2 is $76,131.

7.3.3 Alternative PR3: Capping and Land Use Controls

Alternative PR3 includes capping and land use controls. The estimated area for capping is 840 square feet.

7.3.3.1 Overall Protection of Human Health and the Environment

Alternative PR3 provides protection of human health and the environment because the alternative achieves the applicable PRG for the CEC risk driver in shallow soil, thus meeting the RAO.

7.3.3.2 Compliance with ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

7.3.3.3 Long-term Effectiveness and Permanence

- Magnitude and Type of Residual Risk - Reductions in contaminant concentrations, and thus potential exposures and risk, are estimated at the completion of construction. The residual concentrations for each RAO are shown in Table 7-3 and described as follows:

  RAO 1 – Not applicable for this AOPC.

  RAO 2 - Alternative PR3 results in a 95% UCL of 72 mg/kg for the CEC, thus meeting the PRG.

  Land use controls are included in the alternative to restrict actions that would expose buried contamination or significantly alter exposure point concentrations.

- Hot Spots – no "highly concentrated" hot spots were identified in the Pistol Range AOPC.

- Adequacy and Reliability of Controls - Capping is a reliable and proven technology as long as it is designed for the appropriate environmental and anthropogenic conditions.

  Operation and maintenance activities and land use controls will be implemented to assure protectiveness and reliability of the remedial action. In addition to confirmation sampling, O&M Monitoring consisting of visual cap and land use control inspections and reporting is assumed to be necessary. O&M activities such as cap repair will be required if any issues are reported during monitoring. Activities such as sign maintenance are anticipated for the land use controls.

7.3.3.4 Reductions in Toxicity, Mobility, or Volume through Treatment

This alternative does not include any treatment.

7.3.3.5 Short-term Effectiveness

- Community and Worker Protection - This alternative involves excavation and import of material. Construction is assumed to proceed for approximately one month. Construction and operation activities may result in temporary noise, light, odors, potential air quality impacts and disruptions to community and workers.

  Measures to minimize short-term risks to the community will be addressed through implementation of health and safety plans and the use of BMPs. Examples of BMPs include pollution controls to minimize emissions and odors from construction activities and isolating work areas with an adequate buffer zone so that occupational workers avoid the construction area.

- Environmental Impacts - Environmental impacts would result from construction efforts. Such impacts would include ground disturbance for creation of haul roads, air emissions from construction equipment, and nuisance noise. Best management practices can be utilized to minimize many of these impacts.

- Time to Achieve Cleanup Objectives - Achievement of cleanup objectives is expected to occur at completion of remedy implementation (1 month).

7.3.3.6 Implementability

Alternative PR3 is administratively and technically feasible. Capping is a common practice and will not likely present unforeseen technical problems or schedule delays during construction of the alternative. Equipment and capping material are also readily available within a reasonable distance of the site.

7.3.3.7 Cost

Estimated total cost to implement Alternative PR3 is $123,307.

7.4 Managing COCs and CECs Other Than Risk Drivers

In addition to the risk driver chemicals identified as part of the RAOs and PRGs development, additional COCs and CECs were identified in both the baseline human health and ecological risk assessments. As summarized in Section 3, COCs and CECs were defined as detected chemicals with a hazard quotient greater than one (for both ecological and human health) or an excess cancer risk estimate greater than 1×10^{-6} (for human health). The risks associated with these non-risk driver COCs and CECs were relatively low compared to risk-driver chemicals identified in Section 4.

Based on the findings of the baseline HHRA, additional COCs were recommended for further consideration in the FS due to both the magnitude and frequency of exceeding risk thresholds. For the Landfill AOPC, those additional COCs identified separate from the risk driver COC include arsenic and total PCBs. Based on the same methodology of evaluating the magnitude and frequency of exceeding risk thresholds, chlordane was also identified as a CEC in addition to the risk driver CEC. In the Sandblast AOPC, other COCs recommended for additional consideration include arsenic, total PCBs, and DEHP. Additionally in the Sandblast AOPC, antimony is a CEC that is not identified as a risk driver. There are no other COCs or CECs for the Pistol Range AOPC recommended for further consideration as part of developing remedial alternatives.

For those COCs or CECs recommended for further consideration in the FS but not identified as risk drivers for formulating remedial alternatives, elevated concentrations are generally collocated with relatively high risk driver concentrations. Because all of the proposed alternatives involve removal or capping of large portions of soil for the Landfill AOPC, it is expected that remedial actions will have similar effects for the COCs and CECs other than risk drivers as they do for risk drivers. That is, remedial actions are expected to reduce surface wide average concentrations of COCs and CECs other than risk drivers such that concentrations are equal to or below background, hazard quotients are below 1, or excess lifetime cancer risks are below $1 \text{x} 10^{-6}$. Future post construction confirmation sampling and long-term monitoring efforts will address these COCs and CECs in addition to the risk driver contaminants.

7.5 Comparative Analysis

The sections above presented a detailed analysis of each remedial alternative developed for each AOPC against the nine evaluation criteria. The results of those analyses are used in this section to compare the relative advantages and disadvantages of the alternatives for each AOPC, consistent with CERCLA guidance. The comparative analysis in the following sections is summarized in Tables 7-4 and 7-5.

The alternatives were first evaluated against the threshold criteria (Overall Protection of Human Health and the Environment and Compliance with ARARs). If an alternative does not meet the threshold criteria, no further analysis is completed because an alternative must comply with these criteria to be selected.

For the CERCLA balancing criteria (long-term effectiveness; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost), the tables compare the alternatives using a three level relative ranking indicator: ○, ◒, and ●. Cost is evaluated by a direct comparison of the present-value estimates.

Comparative analyses of the criteria for each alternative for each AOPC are detailed below.

7.5.1 Landfill AOPC

Ratings for this AOPC are shown in Table 7-6.

7.5.1.1 Overall Protection of Human Health and the Environment

Alternatives L1 and L2 both result in 95% UCL values exceeding PRGs for all risk driver COC and CECs. Because Alternatives L1 and L2 are not protective of human health and the environment (one of the threshold criteria), they are not evaluated further. The remaining three alternatives, L3 through L5, result in calculated concentrations that are at or below risk thresholds or Oregon DEQ default regional background values for the area. Thus, alternatives L3 through L5 provide protection for human health and the environment. Alternatives L3 and L4 provide adequate protection with remedial actions and land use controls, and Alternative L5 provides adequate protection with remedial action.

7.5.1.2 Compliance with ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

7.5.1.3 Long-Term Effectiveness and Permanence

- Magnitude and Type of Residual Risk - Based on the calculated 95% UCLs, residual risks to human health are the same for alternatives L3, L4, and L5. All three alternatives show ● for achievement of RAO 1.

  The 95% UCLs for the risk driver CECs indicate that L3, L4, and L5 each meet the PRG for all CECs. Alternatives L3 and L4 show ◒ and L5 shows ● for achievement of RAO 2 because 1) concentration reductions are slightly higher for L5 than for the other two alternatives, and, 2) L5 removes all landfill material, while Alternatives L3 and L4 do not.

- Hot Spots – The footprint of Alternative L2 remediates 15 of the 17 unique "highly concentrated" hot spots identified based on ODEQ's Guidance for Identification of Hot

Spots (ODEQ, 1998). The footprints of Alternatives L3, L4, and L5 address all of the 17 unique "highly concentrated" hot spots. Therefore, all three alternatives received a ●.

- Adequacy and Reliability of Controls - Alternatives L3 and L4 include land use controls to minimize potential future human health and ecological risks that may occur due to future actions on site. Alternative L5 does not require any type of land use control. Therefore, L3 and L4 received a ◒ for this criterion and L5 received a ● because L3 and L4 require land use controls.

  Alternatives L3 and L4 would require a five-year review while L5 would not. For this criterion, L3 and L4 received a ○ because of the review requirement. Since L5 leaves no contamination on site, it will not require a five-year review and it received a ●.

  Future O&M for L3 would be limited to actions required for the land use controls. Alternative L4 would require cap inspections and repair as necessary as well as O&M for land use controls. Future O&M would not be necessary for L5. The requirement of maintenance and inspections for L4 indicate a ○. Due to minimum O&M requirements, Alternative L3 received a ◒. Alternative L5 received a ● because no monitoring and maintenance is assumed to be necessary.

7.5.1.4 Reduction in Toxicity, Mobility, or Volume through Treatment

None of the alternatives includes any treatment; therefore, each received a ○ for this criterion.

7.5.1.5 Short-term Effectiveness

The calculated value for short-term effectiveness is an average of the criteria described below.

- Community and Worker Protection - Durations for all evaluated alternatives are short and would all be completed in less than a year, therefore all alternatives received the same value. Alternatives L4 and L5 are both estimated at six to eight months for construction duration, whereas L3 has an estimated construction duration of four to six months. Since L4 and L5 are slightly longer, they received a ◒ and L3 received a ● because of its shorter duration.

- Environmental Impacts - Elements of environmental impacts will be the same for all three alternatives that pass the threshold criteria. However, the capping alternative is slightly more preferable and received a ● because environmental impacts will be less than the others due to minimal hauling and excavation.

- Time to Achieve Cleanup Objectives - For all three evaluated alternatives, the time to achieve cleanup objectives is equivalent to the length of time for remedy implementation. Each alternative takes under a year, which is a relatively short timeframe for remediation activities. Alternatives L4 and L5 are both estimated at six to eight months for construction duration, whereas L3 has an estimated construction duration of four to six months. Since L4 and L5 are slightly longer, they received a ◒ and L3 received a ● because of its shorter duration.

7.5.1.6 Implementability

All three are administratively and technically feasible. There may be some challenges with sloped excavation; however, that challenge would be present for all three alternatives. A ● was selected as the value to indicate that differences in implementability are nearly negligible among alternatives meeting threshold criteria.

7.5.1.7 Cost

Generally as the scope and duration of the project increases, the cost also increases. The cost of alternative L5 is more than double the cost of alternatives L3 and L4.

7.5.2 Pistol Range AOPC

Ratings for this AOPC are shown in Table 7-7.

7.5.2.1 Overall Protection of Human Health and the Environment

Alternative PR1 results in 95% UCL values exceeding the PRG for the CEC. Alternative PR1 does not include any type of additional controls or construction, and thus is not protective of the environment. The remaining two alternatives, PR2 and PR3, result in calculated 95% UCLs that are at or below the PRG. Thus, alternatives PR2 and PR3 provide protection for human health and the environment with remedial action.

7.5.2.2 Compliance with ARARs

There are no Federal or Oregon ARARs establishing contaminant specific cleanup values for soil.

7.5.2.3 Long-Term Effectiveness and Permanence

- Magnitude and Type of Residual Risk - The 95% UCLs for lead indicate that PR2 and PR3 each meet the PRG and have equal values. Therefore, both alternatives received a ●.

- Hot Spots – no hot spots were identified in the Pistol Range AOPC. Thus, consideration of each alternative's effectiveness at addressing hot spots does not need to be addressed. Therefore, both alternatives received a ●.

- Adequacy and Reliability of Controls - Alternative PR3 includes land use controls to minimize potential future human impacts to ecological risks. Therefore, PR3 received ○ for land use controls because of long-term reliance on land use controls. Alternative PR2 received a ● because it does not rely on land use controls.

  Alternative PR3 would require a five-year review while PR2 would not. For this criterion, PR3 received a ○ because of the review requirement. Since PR2 leaves no exposed contamination on site and would not require a five-year review, it received a ●.

  Future O&M would not be necessary for Alternative PR2. Alternative PR3 would require cap inspections and repair as necessary as well as O&M for land use controls. The requirement of maintenance and inspections for PR3 received a ○, while PR2 received a ● because no monitoring and maintenance is assumed to be necessary, and thus risk of exposure due to lack of maintenance does not exist.

7.5.2.4 Reduction in Toxicity, Mobility, or Volume through Treatment

None of the alternatives includes any treatment; therefore, each received a ○ for this criterion.

7.5.2.5 Short-term Effectiveness

- Community and Worker Protection - Durations for both evaluated alternatives are short and would all be completed in less than a year. Therefore, all alternatives received the same value. A ● was selected as the value to indicate that all alternatives were nearly average among alternatives.

- Environmental Impacts - Elements of environmental impacts will be the same for both alternatives that pass the threshold criteria. However, the capping alternative is slightly more preferable because environmental impacts will be less than the others due to minimal hauling and excavation and received a ● for this criterion.

- Time to Achieve Cleanup Objectives - For both evaluated alternatives, the time to achieve cleanup objectives is equivalent to the length of time for construction. Both alternatives are estimated to take one month for construction. A ● was selected as the value to indicate that both alternatives were average.

7.5.2.6 Implementability

Both alternatives are administratively and technically feasible. A ● was selected as the value to indicate that both alternatives were average.

7.5.2.7 Cost

Generally as the scope and duration of the project increases, the cost also increases. The cost of PR3 is more than 1.7 times the cost of PR2.

7.6 Summary of Findings and Path Forward

The NCP at 40 CFR §300.430(e)(9) establishes a framework of nine criteria for evaluating remedies. This FS has comparatively evaluated the potential remedial alternatives in each AOPC against seven of these criteria (protectiveness; compliance with ARARs; long-term effectiveness; reduction of toxicity, mobility and volume; short-term effectiveness; implementability; and cost). Two additional criteria (state and community acceptance) will be considered during development of the Proposed Plan. These alternatives were evaluated qualitatively. Specific ratings for each criterion are summarized in Tables 7-6 and 7-7.

USACE will issue a Proposed Plan that identifies the preferred remedial alternative for the Bradford Island Upland OU. Formal public comments will be solicited on the Proposed Plan. After public comments on the Proposed Plan are received and evaluated, USACE will select the final remedial alternative in a Record of Decision.

The FS has assumed that a period of 2 years would be required following the Record of Decision and before the start of remedial construction. During this period, the following activities would occur:

- Sampling and survey to refine the remediation footprints;
- Completion of remedial design;
- Site wide sampling to establish baseline conditions with which future post; remediation monitoring results will be compared; and
- Development and implementation of land use controls as appropriate.